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# Photonuclear Data - Abstract Sheets 1955 - 1982 Volume V (Flourine - Magnesium)

U.S. DEPARTMENT OF COMMERCE  
National Bureau of Standards  
National Measurement Laboratory  
Center for Radiation Research  
Washington, DC 20234

March 1984



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U.S. DEPARTMENT OF COMMERCE  
NATIONAL BUREAU OF STANDARDS



NBSIR 83-2742

**PHOTONUCLEAR DATA - ABSTRACT SHEETS  
1955 - 1982  
VOLUME V (FLUORINE - MAGNESIUM)**

E. G. Fuller, Henry Gerstenberg

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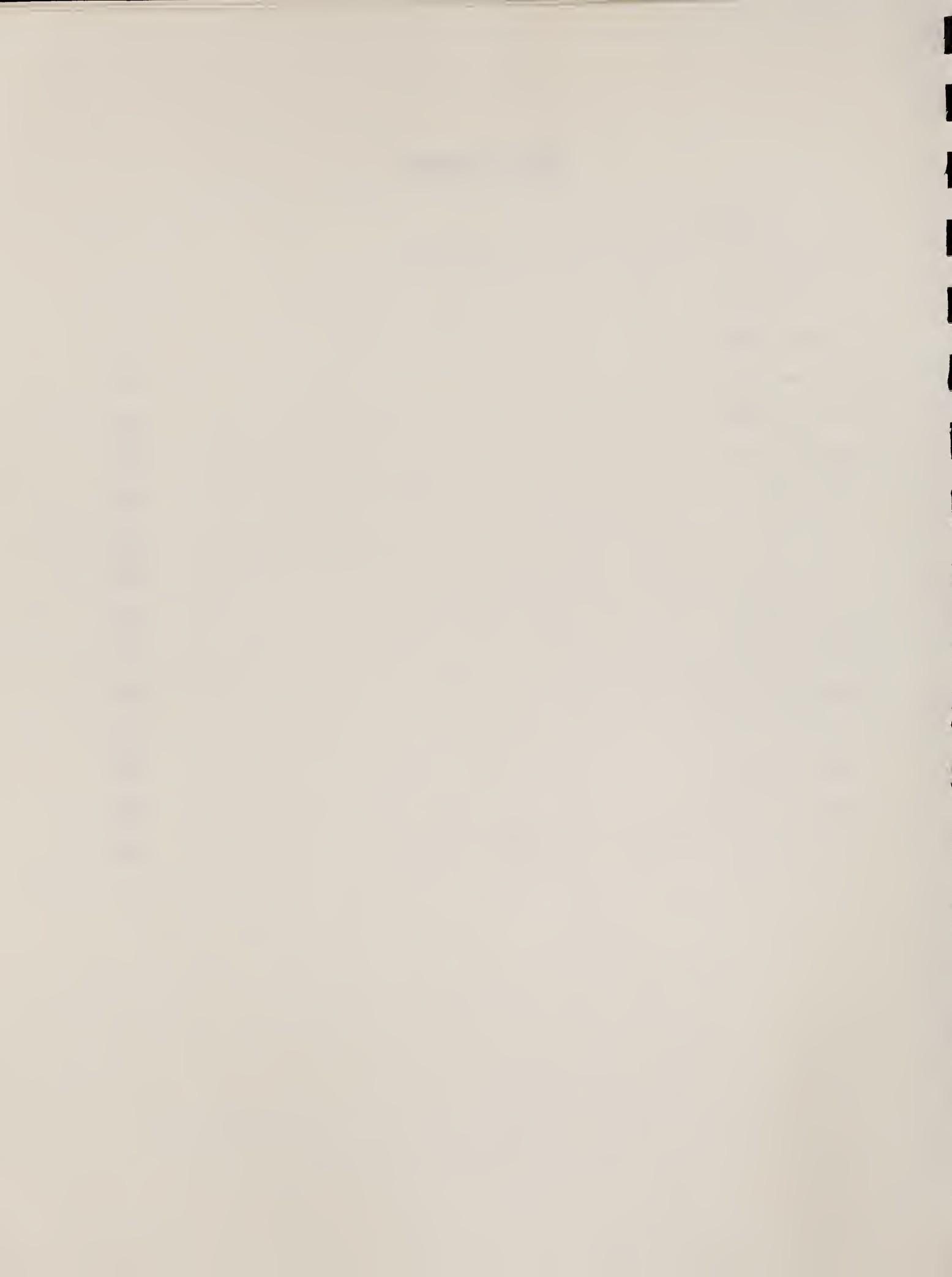
March 1984

**U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, Secretary  
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, Director**



## TABLE OF CONTENTS

Table of Contents . . . . .	i
Introduction. . . . .	1
Fluorine (A=17) . . . . .	3
Fluorine (A=18) . . . . .	11
Fluorine (A=19) . . . . .	17
Fluorine (A=20) . . . . .	101
Neon (Natural). . . . .	105
Neon (A=20) . . . . .	119
Neon (A=22) . . . . .	149
Sodium (A=21) . . . . .	167
Sodium (A=22) . . . . .	173
Sodium (A=23) . . . . .	179
Magnesium (Natural) . . . . .	241
Magnesium (A=24) . . . . .	275
Magnesium (A=25) . . . . .	363
Magnesium (A=26) . . . . .	387
Definition of Abbreviations and Symbols . . . . .	425



Photonuclear Data-Abstract Sheets  
1955-1982

I. Introduction

As used in connection with this collection of data-abstract sheets, the term photonuclear data is taken to mean any data leading to information on the electromagnetic matrix element between the ground state and excited states of a given nuclide. The most common types of reactions included in this compilation are:  $(e,e')$ ,  $(\gamma,\gamma)$ ,  $(\gamma,\gamma')$ ,  $(\gamma,n)$ ,  $(\gamma,p)$ , etc. as well as ground-state particle capture reactions, e.g.  $(\alpha,\gamma_0)$ . Two reactions which fit the matrix element criterion are not included in the compilation because of their rather special nature. These are heavy particle Coulomb excitation and the thermal neutron capture reaction  $(n,\gamma_0)$ . While the energy region of particular interest extends from 0 to 150 MeV, papers are indexed which report measurements in the region from 150 MeV to 4 GeV. Most of the experiments listed are concerned with the excitation energy range from 8 to 30 MeV, the region of the photonuclear giant resonance.

The hierarchical grouping of the photonuclear data-abstract sheets within the file is by: 1. Target Element, 2. Target Isotope, and 3. by the Bibliographic Reference Code assigned to the paper from which the data on the sheet were abstracted. In this file, colored pages are used to mark the beginning and end of the sheets for each chemical element. A brief historical sketch of the element is given on the divider sheet marking the start of each section; the information for this sketch was derived from references such as the Encyclopaedia Britannica. In those cases where the sheets for a given element make up a major part of a volume, colored pages are also used to delineate sections pertaining to the individual isotopes of the element. Each of the sections of the file, as delineated by two colored divider sheets, represents a 27 year history of the study of electromagnetic interactions in either a specific nuclide or a specific element.

The data-abstract sheets are filed under the element and/or isotope in which the ground-state electromagnetic transition takes place. For example, the abstract sheet for a total neutron yield measurement for a naturally occurring copper sample would appear in the elemental section of the copper file. On the other hand, a measurement of the  $^{62}\text{Cu}$  9.73 minute positron activity produced in the same sample by photons with energies below the three-neutron separation energy for  $^{65}\text{Cu}$  (28.68 MeV) would be filed with the sheets for  $^{63}\text{Cu}$ . Similarly a measurement of the ground-state neutron capture cross section in  $^{12}\text{C}$  would be filed under  $^{13}\text{C}$  while the corresponding ground-state alpha-particle capture cross section would be filed under  $^{16}\text{O}$ .

At the end of this volume there is a master list of the abbreviations that have been used in the index section of the abstract sheets. The listings are those used in the final published index, Photonuclear Data Index, 1973-1981, NBSIR 82-2543, issued in August 1982 by the U. S. Department of Commerce, National Bureau of Standards, Washington, DC 20234. In some cases two notations are entered for the same quantity. The second entry is the abbreviation that was used in one or more of the earlier published editions of the index.



FLUORINE  
Z=9

Fluorine is the most reactive of all known chemical elements; this property hindered its original preparation and makes its handling even difficult today. This extreme reactivity brought agony and death to some of the pioneer investigators.

Georgius Agricola (1494-1555), a German scholar and man of science, wrote in his first mineralogical work Bermannus (1530), that fluorspar was used as a flux in metal smelting; the stones melted in the heat of the fire and caused the material in the fire to become more fluid. In 1670, Heinrich Schwanhard of Nuremberg treated the mineral with strong acids and discovered he could etch glass with the solution. He was a member of a family of glass cutters and raised the etching process to a high art by making scenes, in relief on glass, for Emperor Charles II. Scheele did extensive investigations of fluorspar and published papers in 1780 and 1786 claiming that fluorspar contained a peculiar acid; he called it "fluoric" (from the Latin "*fluo*", flow). This new acid immediately aroused widespread interest. Sir Humphry Davy (1778)-1829) and A. -M. Ampere (1775-1836) recognized in 1813 that the acid must be a compound of hydrogen and an unknown element for which the name "fluorine" was suggested by Ampere. Davy made numerous attempts to isolate the element and it was not until 1886 that Henri Moissan (1852-1907), made a successful preparation. This method used a platinum cell with platinum electrodes but the weight loss of the platinum exceeded the weight of the fluorine produced! The problem of making fluorine on a large scale was not solved until after 1939 when uranium hexafluoride became needed as part of the atomic energy program.



Elem. Sym.	A	Z
F	17	9

Method Van de Graff; NaI

Ref. No.  
63 Se 1 JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$O^{16}(p,\gamma)$	$E_p =$ 3.4-3.5					
	$E_{p0} =$ 3.473	$E_{\gamma_0} =$ 3.86	$\Gamma_\gamma =$ $0.11 \pm 0.02$ eV		$5/2^-$	This $\Gamma_\gamma$ gives a radiative lifetime of $(0.6 \pm 0.1) \cdot 10^{-14}$ sec.

Table I. Coefficients obtained to a least-squares fit of the expression  $A_0 + \sum_{n=1}^4 A_n p_n$  to the data in Figs. 2-10. Quantity  $p_n$  is expressed in arbitrary units.

$E_p$ (MeV)	$A_0$	$A_1$	$A_2$	$A_3$
3.473	$1.18 \pm 0.02$	$0.06 \pm 0.02$	$0.47 \pm 0.02$	$0.16 \pm 0.04$
3.470	$1.08 \pm 0.02$	$0.16 \pm 0.02$	$0.39 \pm 0.11$	$0.20 \pm 0.02$
3.465	$0.10 \pm 0.02$	$-0.10 \pm 0.02$	$0.05 \pm 0.02$	$-0.05 \pm 0.02$

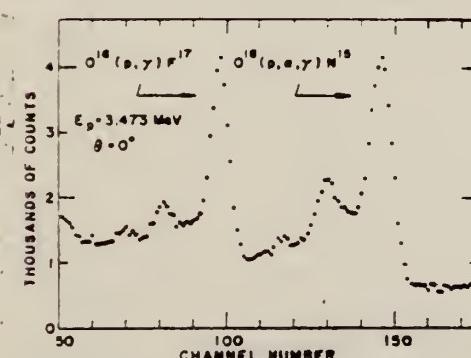


FIG. 1. NaI pulse-height spectrum for radiation emitted at  $0^\circ$  in proton bombardment ( $E_p = 3.473$  MeV) of a tantalum oxide target. The energy is 3.86 MeV for the resonant capture radiation.

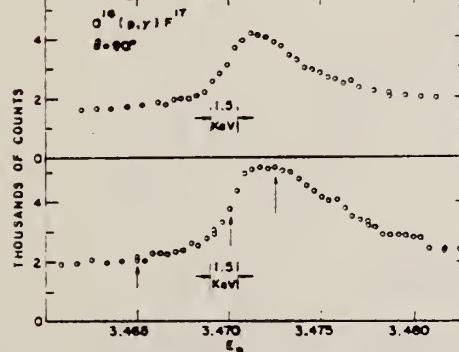


FIG. 2. Differential yield ( $\theta = 90^\circ$ ) for  $O^{16}(p,\gamma)F^{17}$  for two tantalum oxide targets of different thickness. Each point gives the total count in the channels corresponding to the 3.86-MeV peak; no background has been subtracted. Well below resonance the actual yield of 3.86-MeV radiation is less than 0.1 times the on-resonance value. The resonant energy is taken equal to 3.476 MeV. The arrows indicate points at which angular distributions measured with the target used in the lower part of Fig. 2. The distributions are normalized to unity at  $90^\circ$ . The indicated errors are statistical. The curves drawn are based on the coefficients of Table I.

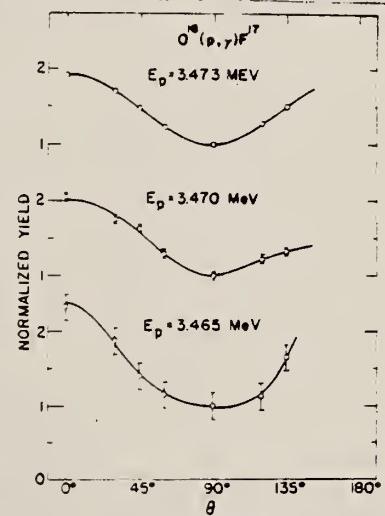
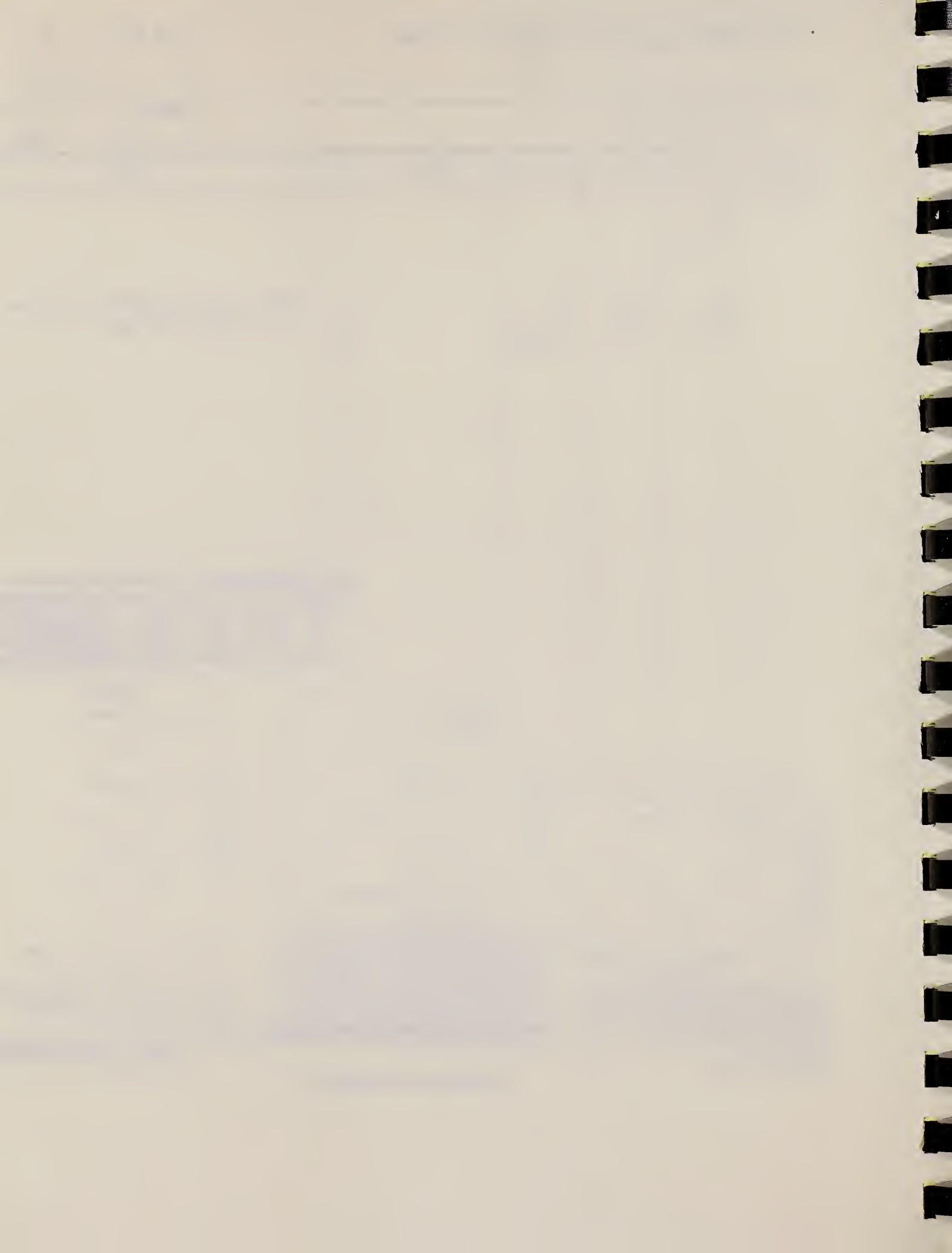


FIG. 3. Angular distributions measured with the target used in the lower part of Fig. 2. The distributions are normalized to unity at  $90^\circ$ . The indicated errors are statistical. The curves drawn are based on the coefficients of Table I.



ELEM. SYM.	A	Z
F	17	9
REF. NO.	75 Ch 1	hmg

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE	RANGE	
P, G	ABX	1 - 3	D	0 - 2	SCD-D
		(.8 - 2.4)		(.4 - 2.0)	DST

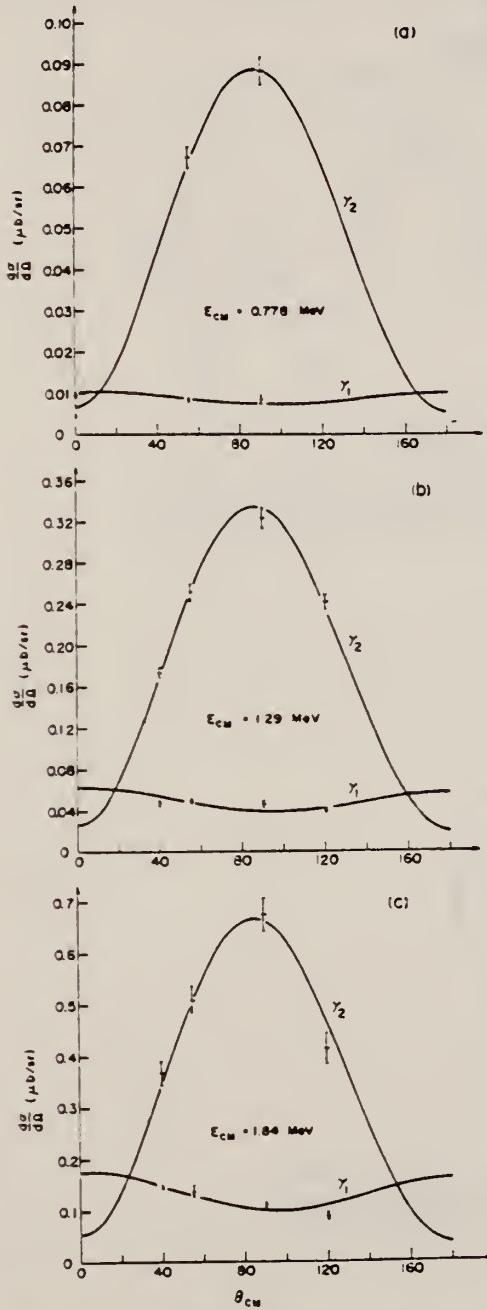


FIG. 6. The angular distributions of the  $^{16}\text{O}(\text{p},\gamma)^{17}\text{F}$  gamma rays at three energies. The experimental points have been normalized to give the best fit to the smoothed theoretical cross section.

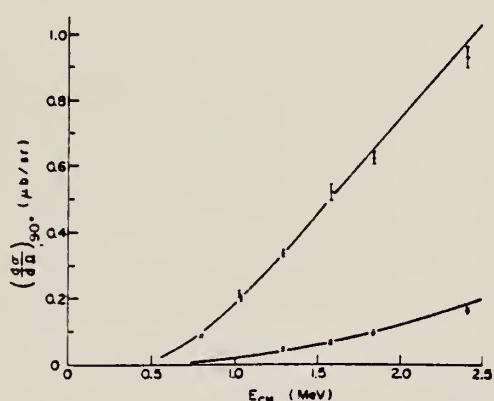


FIG. 7.  $^{16}\text{O}(\text{p},\gamma)^{17}\text{F}$  differential capture cross section at  $90^\circ$  for transitions to the  $1/2^+$  first excited state ( $\gamma_2$ ) and  $5/2^+$  ground state ( $\gamma_1$ ). The experimental cross sections have been normalized to the proton elastic scattering cross section. The solid curves are the theoretical cross sections.

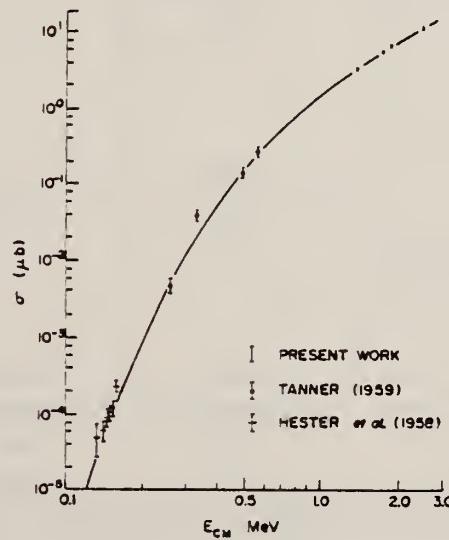


FIG. 8.  $^{16}\text{O}(\text{p},\gamma)^{17}\text{F}$  total cross section. The solid curve is the theoretical cross section. Data points above 1 MeV are from the present work; those between 250 and 600 keV are from Tanner (1959); and those below 200 keV are from Hester *et al.* (1958).

(over)

TABLE 4. 90° differential and total cross sections for proton capture to the ground state ( $\gamma_1$ ) and first excited state ( $\gamma_2$ ) of  $^{17}\text{F}$

Mean CM energy (MeV)	$\gamma_1$		$\gamma_2$	
	$d\sigma/d\Omega$ (90°) ( $\mu\text{b}/\text{sr}$ )	$\sigma$ ( $\mu\text{b}$ )	$d\sigma/d\Omega$ (90°) ( $\mu\text{b}/\text{sr}$ )	$\sigma$ ( $\mu\text{b}$ )
0.795			0.086 ± 0.004	0.73 ± 0.04
1.024			0.212 ± 0.011	1.78 ± 0.09
1.029			0.195 ± 0.007	1.64 ± 0.06
1.288	0.046 ± 0.005	0.69 ± 0.08	0.337 ± 0.010	2.83 ± 0.08
1.572	0.066 ± 0.006	1.01 ± 0.09	0.521 ± 0.025	4.36 ± 0.21
1.836	0.096 ± 0.006	1.52 ± 0.10	0.628 ± 0.020	5.27 ± 0.17
2.404	0.164 ± 0.008	2.66 ± 0.13	0.940 ± 0.030	7.88 ± 0.25

METHOD	REF. NO.						
	75 Ha 5		hmg				
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR			ANGLE
			TYPE	RANGE	TYPE	RANGE	
P, G	ABX	15- 31	D	15- 32	NAI-D		DST

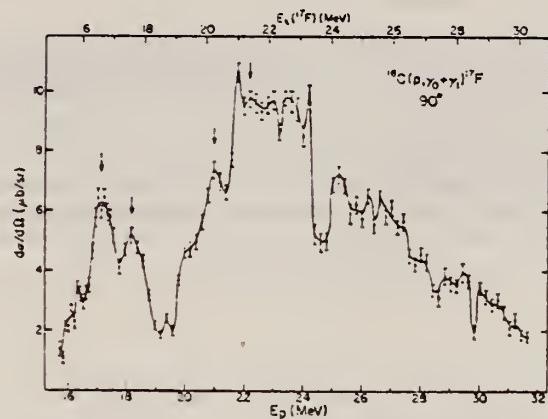


FIG. 3. Excitation curve for the summed transitions  $\gamma_0 + \gamma_1$ . The solid line is drawn through the data to guide the eye. Arrows indicate energies where angular distributions were taken.

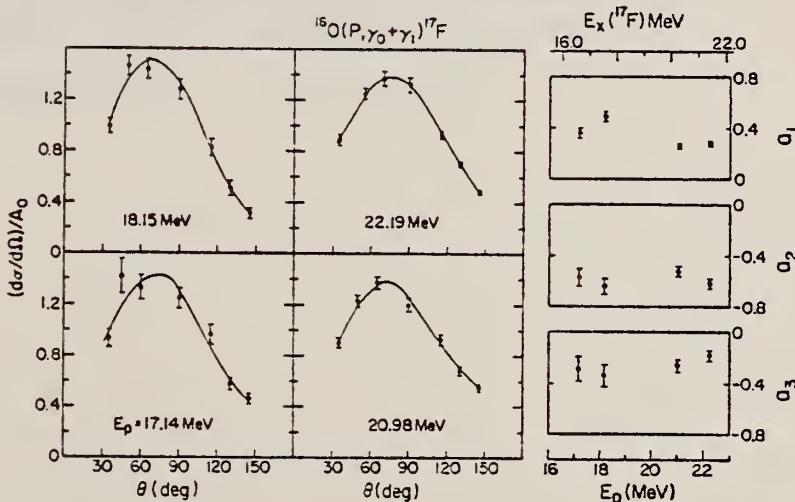


FIG. 4. Angular distributions of the  $\gamma_0 + \gamma_1$  yield at 17.14, 18.15, 20.98, and 22.19 MeV, i.e., the energies indicated by arrows in Fig. 3. Solid curves are fits with Legendre polynomials up to and including  $P_3$  terms. The normalized Legendre coefficients  $a_1$ ,  $a_2$ , and  $a_3$  obtained from the fits are plotted on the right-hand side of the figure.

TABLE IV. Summary of theoretical and experimental results.

	General rules	1p and 2p-1h calc. <sup>a</sup>	Exp.
$\sigma_0 = \int \sigma dE$ (MeV mb)	= 60 NZ/A 254	$\sigma_0(T = \frac{1}{2}) = 129$ $\sigma_0(T = \frac{3}{2}) = 221$ $\sigma_0(\text{total}) = 350$	$\sigma_0(\gamma, p_0)$ $\leq 10.2$
$\sigma_{-1} = \int \sigma / E dE$ (mb)	= $0.36A^{4/3}$ 15.7	$\sigma_{-1}(T = \frac{1}{2}) = 6.0$ $\sigma_{-1}(T = \frac{3}{2}) = 8.9$ $\sigma_{-1}(\text{total}) = 14.9$	
$\sigma_{-1}(T + 1) / \sigma_{-1}$	0.60 <sup>b</sup> 0.59 <sup>c</sup>	0.60	
$E_{\text{GDR}} = \sigma_0 / \sigma_{-1}$ (MeV)		$E_{T=1/2} = 21.4(20.4)$ $E_{T=3/2} = 24.8$	$E_{T=1/2} = 22.0(15.4 - 30.4 \text{ MeV})$ $E_{T=1}(^{16}\text{O}) = 22.4(16.3 - 29 \text{ MeV})^d$
$\Delta E = E_{T=3/2} - E_{T=1/2}$ (MeV)	= $U(T_{\frac{3}{2}} - 1)/A$ = 5.3 ( $U = 60 \text{ MeV}$ ) <sup>e</sup> = 1.8 ( $U \approx 20 \text{ MeV}$ ) <sup>f</sup>	3.4(4.4) - $U = 39 \text{ MeV}$	

<sup>a</sup> Numbers in this column are from case I calculation except for numbers in parenthesis, which are from case II.<sup>b</sup> See Ref. 17.<sup>c</sup> See Ref. 19.<sup>d</sup> Calculated from experimental data of Refs. 7 and 8.<sup>e</sup> See Ref. 2.<sup>f</sup> See Ref. 3.<sup>2</sup> R.O. Akyuz and S. Fallieros, Phys. Rev. Lett. 27, 1016 (1971).<sup>3</sup> Renzo Leonardi, Phys. Rev. Lett. 28, 836 (1972).<sup>7</sup> W.J. O'Connell, Ph.D. Thesis, Stanford Univ. 1970  
(unpublished).<sup>8</sup> N.W. Tanner *et al.*, Nucl. Phys. 52, 45 (1964).<sup>17</sup> S. Fallieros and B. Gouillard, Nucl. Phys. A147, 593 (1970).<sup>18</sup> E. Hayward, B.F. Gibson, J.S. O'Connell, Phys. Rev. C5, 846 (1972).

ELEM. SYM.	A	Z
F	17	9

METHOD	REF. NO.
	79 Kh 7 hg

Abstract: Measurements have been made of some parameters of the second and sixth  $T = \frac{1}{2}$  states in  $^{17}\text{F}$ . For the second state, the resonance energy was found to be  $E_p = 12.707 \pm 0.001$  MeV ( $E_1 = 12.550 \pm 0.001$  MeV), which agrees with and improves on the accuracy of earlier work. For the sixth  $T = \frac{1}{2}$  state, at  $E_p = 14.435$  MeV, the  $\gamma$ -decay was determined to be predominantly  $\gamma_0$  with a branch to the first excited state of  $\Gamma(\gamma_1)/\Gamma(\gamma_0) \leq 0.14$ . Together with other work, this determines  $J^*$  to be  $\frac{3}{2}^-$ . The capture strength is found to be  $(2J+1)\Gamma_p\Gamma/\Gamma = 11.4 \pm 2.6$  eV.

### BRANCHING RATIO, SPIN

E NUCLEAR REACTIONS  $^{16}\text{O}(p, \gamma)$ ,  $E = 12-15$  MeV; measured  $\sigma(E_p)$ .  $^{17}\text{F}$  deduced  $E_{res}$ ,  $J^*$ , capture strength.

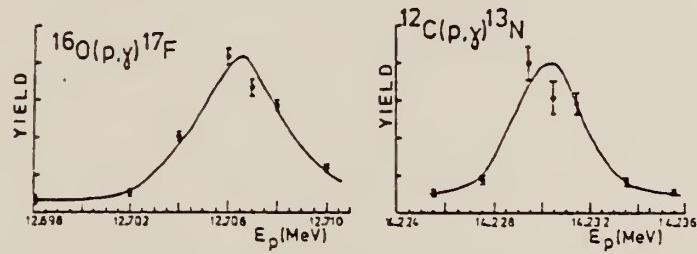


Fig. 2. Gamma yield for  $T = \frac{1}{2}$  resonances in  $^{16}\text{O}(p, \gamma)^{17}\text{F}$  and  $^{12}\text{C}(p, \gamma)^{13}\text{N}$  as a function of proton energy at the target centre.



F  
A=18

F  
A=18

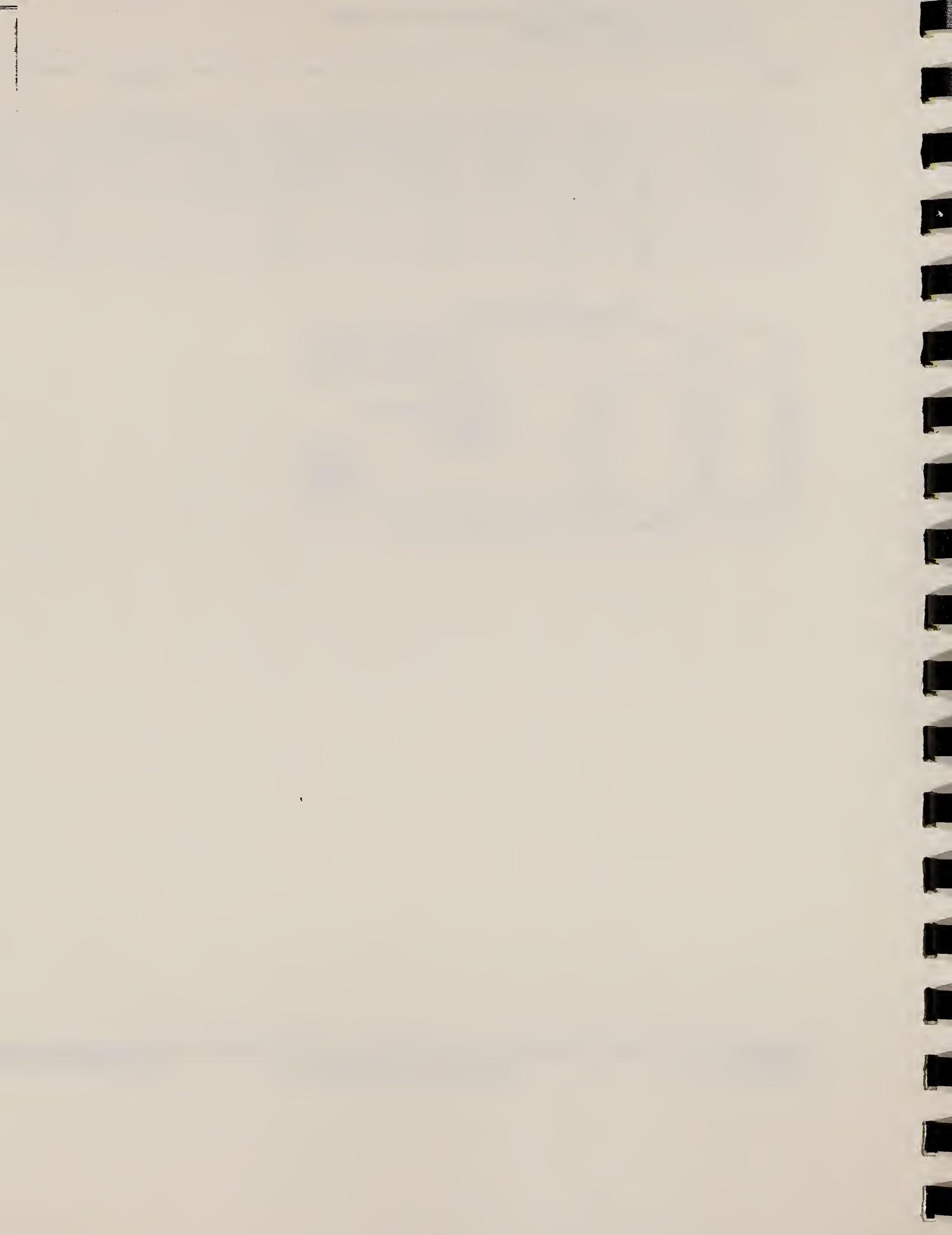


METHOD					REF. NO.		
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
A,G	ABX	4-5	D	0-2	ACT-I		4PI

TABLE I  
 Summary of  $^{14}\text{N}(\text{x},\gamma)^{18}\text{F}$  results

$E_x$ (MeV)	$E_\gamma$ (MeV)	$J^\pi; T$	$(2J+1)\Gamma_x\Gamma_\gamma/\Gamma \text{ cV(lab)}$	
			Present experiment	Parker <sup>a</sup>
0.310	4.656	4 <sup>+</sup> ; 1	$< 2 \times 10^{-5}$	
0.417	4.739	0 <sup>+</sup> ; 1	forbidden by selection rules	
0.559	4.849	1 <sup>-</sup> ; 0	$2.79 \pm 0.5 \times 10^{-4}$	
0.698	4.957	2 <sup>+</sup> ; 1	$< 0.5 \times 10^{-4}$	
1.140	5.301	1 <sup>-</sup> , 2, 3, 4 <sup>+</sup> ; 0	$0.108 \pm 0.015$	$0.084 \pm 0.004$
1.395	5.501			$0.027 \pm 0.003$
1.532	5.607	(1 <sup>-</sup> ; 0)		$4.80 \pm 0.40$
1.619	5.674	(1 <sup>-</sup> ; 0)		$1.35 \pm 0.15$

<sup>a</sup> Ref.<sup>a</sup>) - P.D. Parker, Phys. Rev. 173 (1968) 1021.



ELEM. SYM.	A	Z
F	18	9

METHOD	REF. NO.	
	73 Se 3	egf

6.14 MEV LEVEL

TABLE I  
Electromagnetic decay properties for observed  $^{18}\text{F}$  levels

Transition $E_i \rightarrow E_f$ (MeV)	$J_i^{\pi} \rightarrow J_f^{\pi}$	$A_2$	$A_4$	$\delta$	$\Gamma_{\gamma}^*$ (meV)	$ M ^2$ (W.u.) <sup>a</sup>
6.10 $\rightarrow$ 1.12	$4^- \rightarrow 5^+$	$0.03 \pm 0.07$	$0.09 \pm 0.09$	$0.18 \pm 0.11$	$14 \pm 11$ <sup>b</sup>	$\{(E1) (0.23 \pm 0.18) \times 10^{-3}$
6.10 $\rightarrow$ 2.10	$4^- \rightarrow 2^-$	$0.31 \pm 0.12$	$0.04 \pm 0.15$	$-0.07 \pm 0.11$	$6 \pm 5$ <sup>b</sup>	$\{(M2) \leq 3$
6.14 $\rightarrow$ 0	$0^+ \rightarrow 1^+$	$0.01 \pm 0.03$	$0.05 \pm 0.04$	0	$\geq 400 \pm 120$	$(E2) 2.5 \pm 1.9$
6.14 $\rightarrow$ 1.70	$0^+ \rightarrow 1^+$	$0.12 \pm 0.12$	$0.12 \pm 0.19$	0	$\geq 74 \pm 8$	$(M1) \geq 0.08 \pm 0.02$
6.14 $\rightarrow$ 3.72	$0^+ \rightarrow 1^+$	$0.05 \pm 0.08$	$0.10 \pm 0.11$	0	$\geq 270 \pm 80$	$(M1) \geq 0.04 \pm 0.004$
6.16 $\rightarrow$ 0.94 $\rightarrow$ 0 <sup>c</sup>	$3^+ \rightarrow 3^+ \rightarrow 1^+$	$0.27 \pm 0.07$	$-0.04 \pm 0.10$	$0.11 \pm 1.1$	$160 \pm 50$	$(M1) (5.3 \pm 2.5) \times 10^{-2}$
6.24 $\rightarrow$ 2.10 <sup>d</sup>	$3^- \rightarrow 2^-$	$-0.20 \pm 0.02$	$-0.01 \pm 0.05$	$-0.06 \pm 0.02$	$1900 \pm 860$ <sup>e</sup>	$\{(M1) 1.3 \pm 0.6$
6.24 $\rightarrow$ 2.10	$3^- \rightarrow 2^-$	$0.06 \pm 0.05$	$0.06 \pm 0.06$		$1900 \pm 860$ <sup>e</sup>	$\{(E2) 2.1 \pm 1.7$
6.24 $\rightarrow$ 3.79	$3^- \rightarrow (3^-)$	$0.04 \pm 0.11$	$0.09 \pm 0.18$		$300 \pm 140$ <sup>e</sup>	
6.28 $\rightarrow$ 0.94 $\rightarrow$ 0 <sup>c</sup>	$2^+ \rightarrow 3^+ \rightarrow 1^+$	$-0.13 \pm 0.08$	$-0.01 \pm 0.10$	$0.06 \pm 0.04$	$350 \pm 120$	$\{(M1) (0.11 \pm 0.04)$
6.39 $\rightarrow$ 0.94	$2, 3^- \rightarrow 3^+$	$0.25 \pm 0.06$	$-0.05 \pm 0.09$			$\{(E2) 0.12 \pm 0.12$
6.65 $\rightarrow$ 0.94	$2 \rightarrow 3^+$	$0.00 \pm 0.05$	$-0.01 \pm 0.08$		$110 \pm 55$ <sup>f</sup>	
6.65 $\rightarrow$ 2.10	$2 \rightarrow 2^-$	$-0.08 \pm 0.03$	$-0.06 \pm 0.04$		$640 \pm 310$ <sup>f</sup>	
6.65 $\rightarrow$ 3.13	$2 \rightarrow 1^-$	$0.11 \pm 0.07$	$0.06 \pm 0.09$		$140 \pm 70$ <sup>f</sup>	
6.78 $\rightarrow$ 0.94	$4^+ \rightarrow 3^+$	$0.08 \pm 0.12$	$0.18 \pm 0.15$	$-0.13 \pm 0.11$	$11 \pm 4$	$\{(M1) (2.6 \pm 0.9) \times 10^{-3}$
6.78 $\rightarrow$ 1.12	$4^+ \rightarrow 5^+$	$0.50 \pm 0.10$	$0.02 \pm 0.12$	$-1.1 \pm 0.3$	$29 \pm 10$	$\{(E2) \leq 0.03$
6.78 $\rightarrow$ 4.65	$4^+ \rightarrow 4^+$	$0.29 \pm 0.05$	$-0.05 \pm 0.08$	$-0.3 \pm 0.2$	$35 \pm 12$	$(M1) (3.3 \pm 1.6) \times 10^{-3}$
6.87 $\rightarrow$ 0.94	$3, 4, 5 \rightarrow 3^+$	$-0.1 \pm 0.2$	$0.7 \pm 0.3$			$(E2) 1.2 \pm 0.5$
6.87 $\rightarrow$ 4.65	$3, 4, 5 \rightarrow 4^+$	$0.19 \pm 0.05$	$0.06 \pm 0.06$			$(M1) 0.16 \pm 0.06$
						$(E2) < 80$

Angular distribution data  $A_1$  are from the  $^{17}\text{O}(p, \gamma)^{18}\text{F}$  reaction, and in the case of one transition from the 6.24 MeV level, from the  $^{14}\text{N}(\alpha, \gamma)^{18}\text{F}$  reaction. The energy shifts as functions of angle for the transitions from all of the resonant levels showed full Doppler shifts.

<sup>a</sup>)  $|M|^2 = \Gamma_{\gamma\gamma}/\Gamma_W$  with  $R_0 = 1.2$  fm.

<sup>b</sup>) The value used,  $\Gamma_{\gamma} = 21 \pm 16$  meV, was calculated from the present strength, Brown's  $\alpha$ -strength<sup>19</sup>, and  $\Gamma_{\alpha}$  from Silverstein<sup>18</sup>. Berka<sup>7</sup> gives  $\Gamma_{\gamma} = 66 \pm 21$  meV. <sup>c</sup>) Angular correlation. <sup>d</sup>) From the  $^{14}\text{N}(\alpha, \gamma)^{18}\text{F}$  reaction. <sup>e</sup>) Using  $\Gamma_{\alpha} \approx 1$  keV  $\pm 30\%$  given by Silverstein<sup>18</sup>.  
<sup>f</sup>) With  $\Gamma_{\alpha}\Gamma_{\gamma}/\Gamma = 0.58 \pm 0.20$  eV deduced from Phillips<sup>20</sup>.

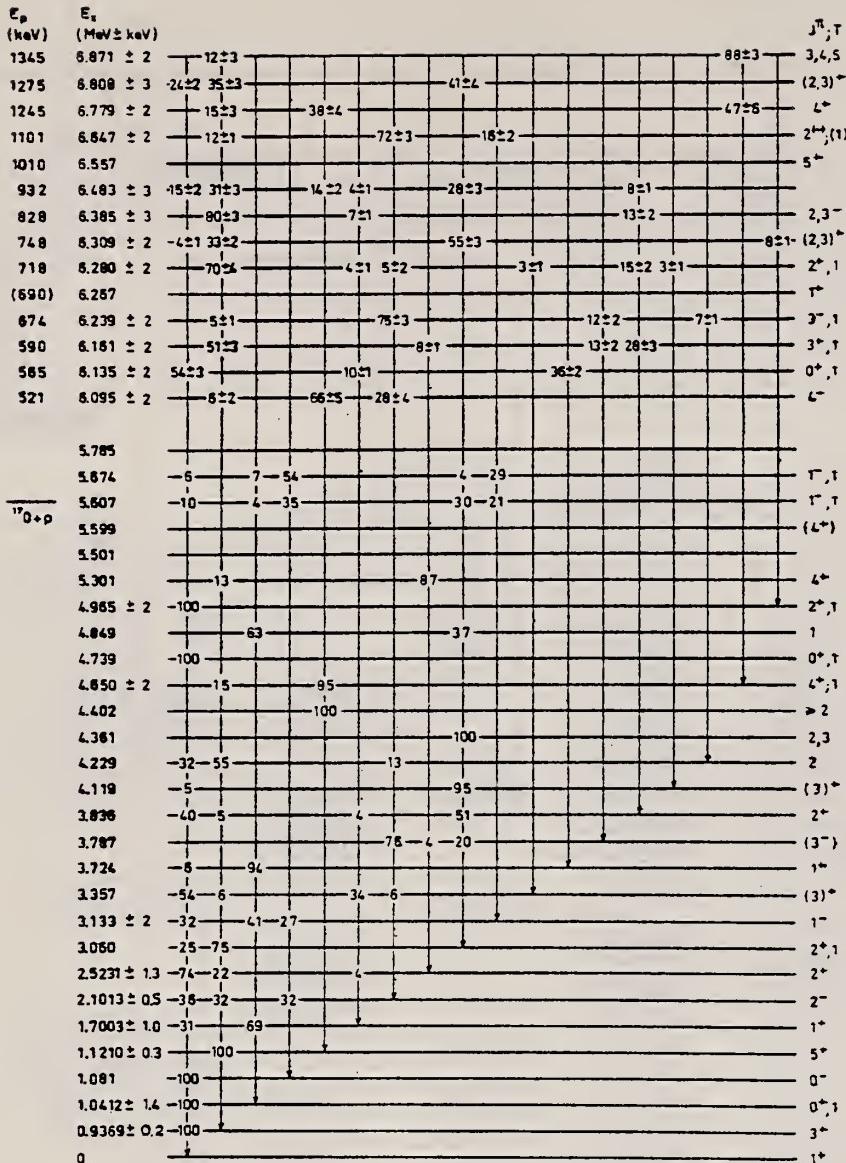
<sup>7</sup> I. Berka et al., Bull. Am. Phys. Soc. 16, 510 (1971).

<sup>18</sup> E. A. Silverstein et al., Phys. Rev. 124, 868 (1961).

<sup>19</sup> R. E. Brown, Phys. Rev. 125, 347 (1962).

<sup>20</sup> W. R. Phillips, Phys. Rev. 110, 1408 (1958).

(over)



### $^{18}\text{F}$

Fig. 2. Energy levels and  $\gamma$ -decay of  $^{18}\text{F}$ . The uncertainty in  $E_\gamma$  is 2 keV. Where an uncertainty is given for  $E_\gamma$  this was determined from our observed  $\gamma$ -ray cascades. The figure includes all reported narrow levels. The  $J^\pi$  of the  $E_\gamma = 5.30, 6.14$  and  $6.56$  MeV levels are from refs. <sup>36, 8</sup>). The level at 6.27 MeV was not seen in ( $p, \gamma$ ). Its  $J^\pi$  is from ref. <sup>18</sup>). Since the  $E_\gamma = 6.56$  MeV level was very weakly excited in the ( $p, \gamma$ ) reaction, it was not possible to establish a decay scheme. The information on the  $E_\gamma = 5.61$  and  $5.67$  MeV doublet are from ref. <sup>37</sup>). All other data below  $E_\gamma = 6$  MeV are taken from ref. <sup>33</sup>).

<sup>8</sup> C. Rolfs et al., Bull. Am. Phys. Soc. 15, 782 (1970).

<sup>35</sup> F. Ajzenberg-Selove, Nucl. Phys. A190 (1972) 1.

<sup>36</sup> C. Rolfs et al., Bull. Am. Phys. Soc. 16, 510 (1971).

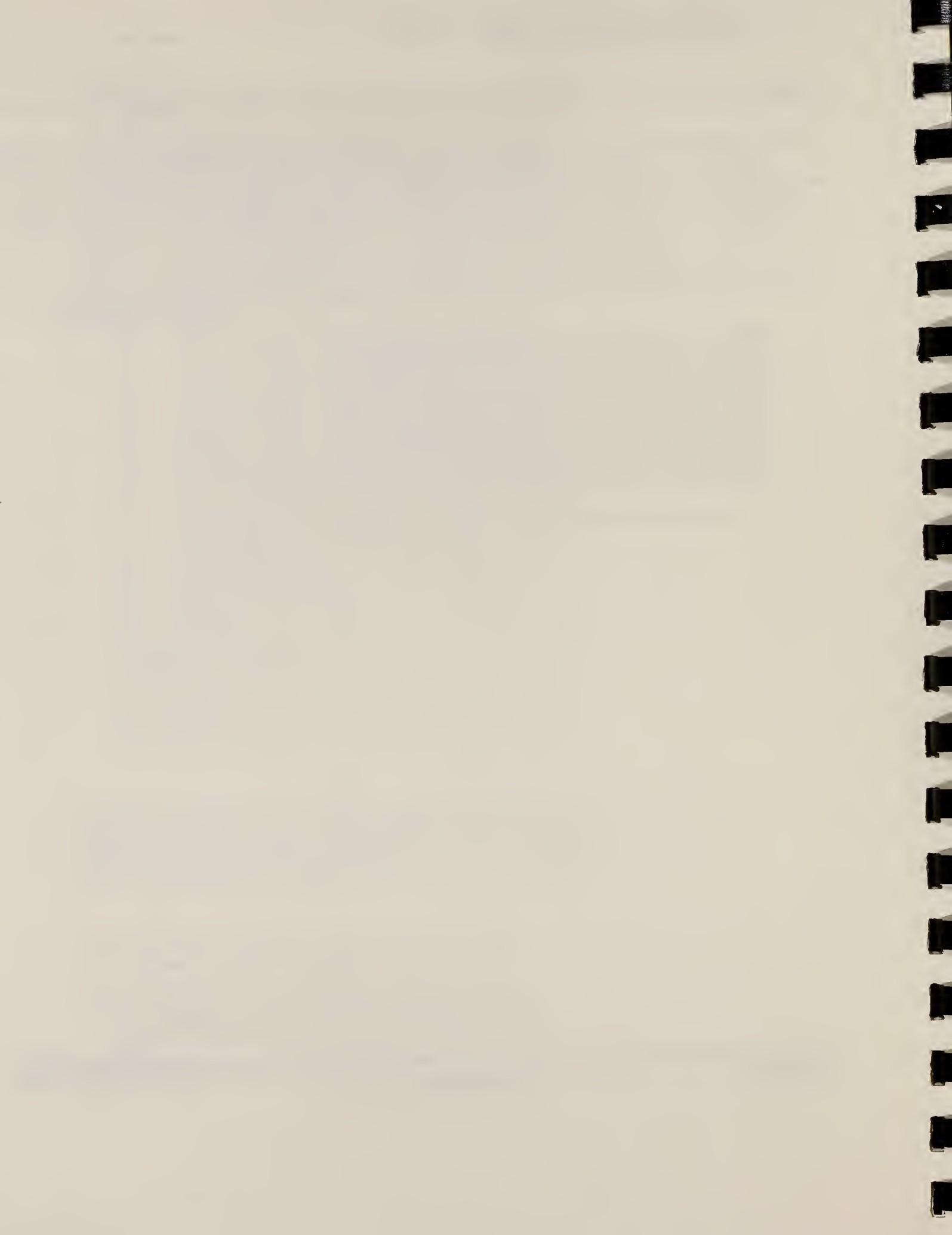
<sup>37</sup> E. K. Warburton et al., Isospin in nuclear physics, ed. D.H. Wilkinson (North-Holland, Amsterdam, 1969) p. 223.

ELEM. SYM.	A	Z
F	18	9

METHOD	REF. NO.	
	78 Be 16	hg
REACTION	RESULT	EXCITATION ENERGY
		SOURCE
		TYPE RANGE
A,G	LFT	6
		D 2
		(6.138) (2.215)

UP. LIM. WIDTH=.002EV

**Summary.** — An experiment on the  $^{14}\text{N}(\alpha, \gamma)^{18}\text{F}$  reaction leading to the parity- and isospin-forbidden  $0^+$  level at 6.138 MeV is reported. A  $^{14}\text{N}$  gas target was exposed to a pulsed singly charged  $\alpha$ -particle beam from the CN accelerator of the Laboratori Nazionali di Legnaro, and  $\gamma$ -rays emitted in coincidence with the beam were measured with a  $90 \text{ cm}^3$  Ge(Li) detector. A similar run with the same target as well as an activation experiment were carried out on the nearby parity-allowed resonance at 6.241 MeV, in order to test the electronic gain and the efficiency in the parity-violating experiment. The energy spectrum from the Ge(Li) shows no peak due to the decay of the 6.138 MeV state and allows to set an upper limit of  $2 \cdot 10^{-3}$  eV for the parity-violating width of this resonance.



F  
A=19

F  
A=19

F  
A=19



ELEM. SYM.	A	Z
F	19	9

METHOD	REF. NO.	
	52 Ho 1	hmg
REACTION	RESULT	EXCITATION ENERGY
		SOURCE
		TYPE RANGE
G, N	ABX	10- 25
G, 2N	ABX	19- 26
		C 10- 25 ACT-I
		C 19- 26 ACT-I

SEE 54TA1 FOR RE-ANALYSIS

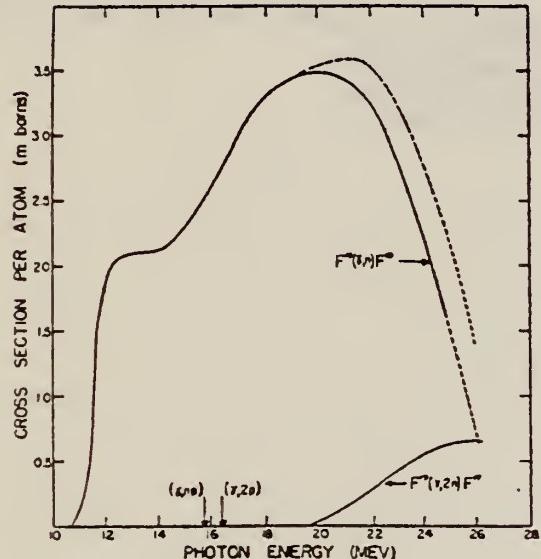


FIG. 2. Cross section vs energy curves for the reactions  $F^{19}(\gamma, n)F^{18}$  and  $F^{19}(\gamma, 2n)F^{17}$ . The dotted line indicates the sum of the two reactions. The  $(\gamma, np)$  and  $(\gamma, 2p)$  calculated thresholds are marked.

TABLE I Information obtained from the  $F^{19}(\gamma, n)F^{18}$  and  $F^{19}(\gamma, 2n)F^{17}$  cross-sectional curves.

Reaction	$F^{19}(\gamma, n)F^{18}$	$F^{19}(\gamma, 2n)F^{17}$
Peak position	20 Mev	26 Mev
Peak cross section	3.48 mb	0.66 mb
Width at half-maximum	12.9 Mev	—
Integrated cross section (to 26 Mev)	0.039 Mev-barns	0.0024 Mev-barns

ELEM. SYM.	A	Z
F	19	9

METHOD

REF. NO.

54 Fe 1

rs

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,Sn	ABX	10-25	C	11-25	BF3-I		4PI

The direct detection of neutrons from ( $\gamma, n$ ) reactions induced by betatron bremsstrahlung has been applied to cross-section determinations using gaseous targets at approximately 100 atmospheres pressure. Results from oxygen are consistent with other determinations. The remaining elements represent new results and show the familiar giant dipole resonance for the photoneutron process. Parameters of the resonances are determined and related to the systematic behavior previously reported for other elements.

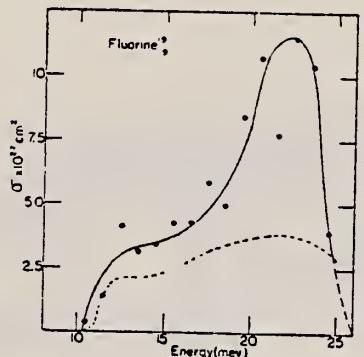


FIG. 7. Photoneutron excitation function for fluorine.

ELEM. SYM.	A	Z
F	19	9
REF. NO.		
54 Ta 1		hmg

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N	ABX	10- 17	C	10- 17	ACT-I		4PI

Measurement is an extension of earlier work:  
 R. J. Horsley, R. N. Haslam, and H. E. Johns,  
 Phys. Rev. 87, 196 (1952)

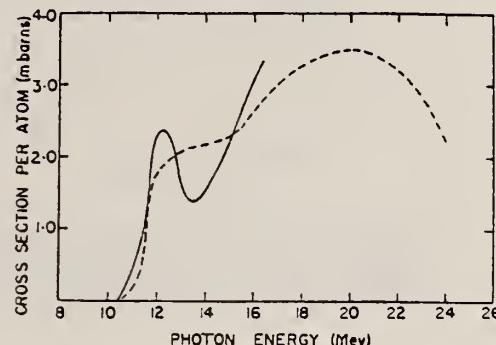


FIG. 1. Cross section for the reaction  $F^{19}(\gamma, n)F^{18}$ . The heavy line shows the cross-section curve determined in the present work, the dotted line the previously reported cross section (5).

METHOD

REF. NO.	55 La 1	JOC
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REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE	RANGE		
G, P	SPC	10 - 17	C	17	EMU-D	DST

$$\int_{10}^{16.5} \sigma \gamma, p = 18 \text{ MeV-mb}$$

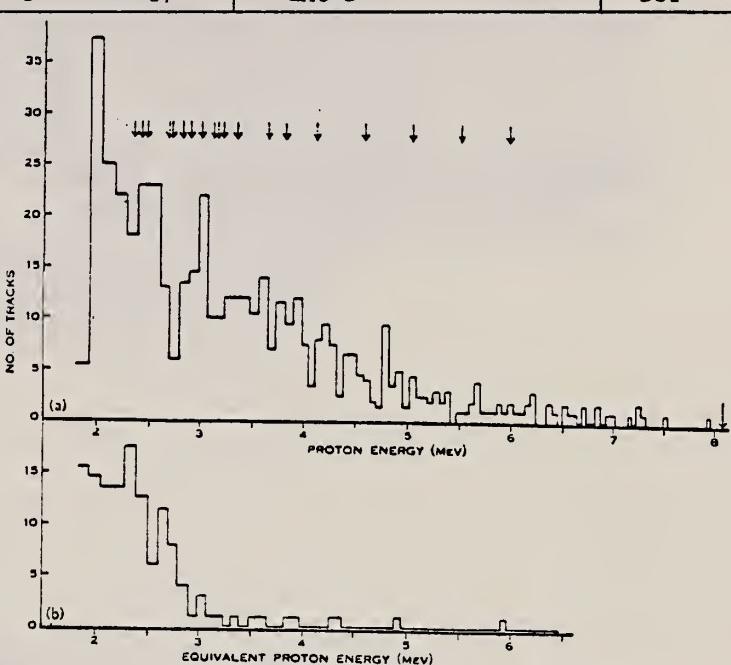


Fig. 2 (a).—Energy distribution of photoprottons from  $^{19}\text{F}$ . The expected positions of proton groups between known energy levels in  $^{19}\text{F}$  and  $^{18}\text{O}$  are indicated by arrows above the histogram as follows:

↓  $^{19}\text{F}^*$  to  $^{18}\text{O}$  (ground state),  
↓  $^{19}\text{F}^*$  to  $^{18}\text{O}^*$  (1.98 MeV state).

(The energy levels in  $^{19}\text{F}$  were observed in  $^{18}\text{O}(p,n)^{19}\text{F}$  (Ajzenberg and Lauritsen 1955).) The limit of resolution is 0.3 MeV.

Fig. 2 (b).—Corresponding background tracks.

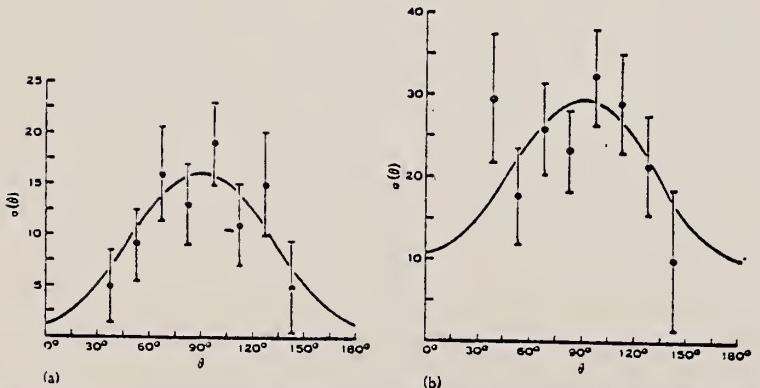


Fig. 3.—Angular distribution of photoprottons from  $^{19}\text{F}$ .  $\theta$  = angle between incident photon and the proton,  $\sigma(\theta)$  = differential cross section (arbitrary units). Vertical lines represent standard deviations of the points.

(a) Energy range 4.4-8.5 MeV. No. of tracks = 75, percentage background = 10, least squares fit to data is shown by curve  $(1 \pm 5) + (15 \pm 7) \sin^2 \theta$ .

(b) Energy range 2.0-4.4 MeV. No. of tracks = 180, percentage background = 13%, least squares fit to data is shown by curve  $(10 \pm 8) + (19 \pm 11) \sin^2 \theta$ .

ELEM. SYM.	F	19	9

METHOD

Linac; counted delayed neutrons from N<sup>17</sup>

REF. NO.

55 Re 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,2P	ABI	THR - 400	C	80-400	ACT-I		4PI

$$\int_{80}^{400} \sigma dE_Y = 0.0037 \text{ MeV-barns.}$$

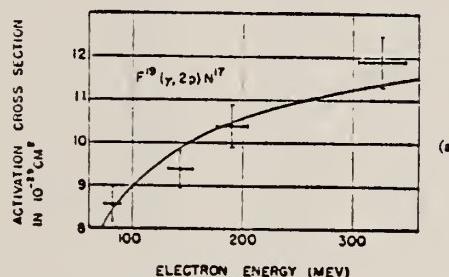


Fig. 3. Yields from the O<sup>16</sup>(γ,p)N<sup>17</sup> and F<sup>19</sup>(γ,2p)N<sup>17</sup> reactions, as functions of radiating electron energy. The solid lines are isochromats of characteristic energy 25 and 40 Mev, corresponding to integrated cross sections of 0.067 and 0.0037 Mev-barn, respectively.

Elem. Sym.	A	Z
F	19	9

Method Betatron; neutron yield; radioactivity; ion chamber

Ref. No.	
58 Be 1	EH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$F^{19}(\gamma, n)$	Bremss. 10-11	10-11				Peak found at $10.47 \pm 0.02$ based on $(\gamma, n)$ thresholds in $F^{19}$ , $N^{14}$ and $C^{12}$ .

METHOD

Betatron

REF. NO.

59 Oc 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, 2N	RLI	THR-100	C	THR-100	ACT-I		4PI

REL TO G, N

TABLE II. Relative integrated cross sections.

Element	$(\gamma, n)$	Position of the peak for $(\gamma, n)$		Position of the peak for $(\gamma, 2n)$	
		Energy	Yield	Energy	Yield
C <sup>12</sup>	1	23 Mev	0.003	42 Mev	
N <sup>14</sup>	1	24 Mev	0.007*		
O <sup>16</sup>	1	22 Mev	0.002	40 Mev	
F <sup>19</sup>	1	20 Mev	0.14	32 Mev	
Na <sup>23</sup>	1	20 Mev	0.05	32 Mev	
P <sup>31</sup>	1	20 Mev	0.06 ( $\gamma, 2p$ ) 0.08 ( $\gamma, 2pn$ )	45 Mev ( $\gamma, 2p$ ) 50 Mev ( $\gamma, 2pn$ )	

\* The  $(\gamma, n)$  integrated cross section was taken from reference 4.

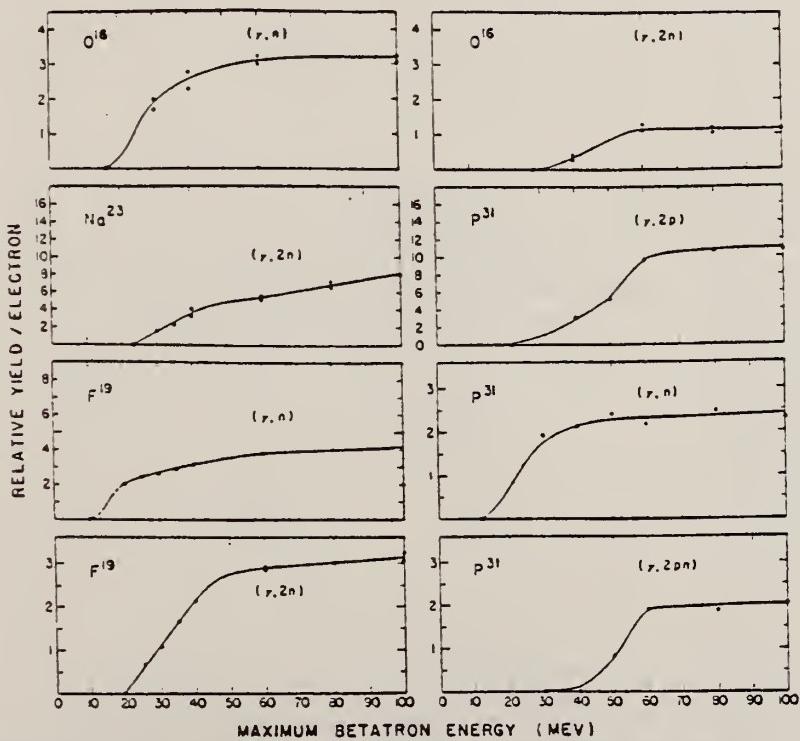


FIG. 1. The energy dependence of several photonuclear reactions. The relative yield scales of different graphs are independent.

Elem. Sym.	A	Z
F	19	9

Method Van de Graaff; electron brems.; Ring scatterer; NaI

Ref. No.  
60 Bo 3 JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
( $\gamma, \gamma$ )	Bremss. 0.5-2.2	1.34			3/2	<p>Mean lifetime <math>t/g</math>:</p> $= (0.5 \pm 0.3) 10^{-13} \text{ sec}$ <p>[resonance scattering]</p> <p>where <math>g = (1+2I)/(1+2I_0)</math>.</p> <p>The 1.34 MeV resonance corresponds to a dipole transition between the 1.46 MeV state and the 0.109 MeV state (from yield curve data).</p>

METHOD

Synchrotron; proton spectrum; angular distribution; nuclear emulsion; cross section.

REF. NO.

60 Fo 2

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, P	RLX	10 - 18	C	16, 19	EMU-D		DST
				(15.5, 19)			

$$\text{In Figure 8, } W(\theta) = 1 + 7 \cos^2\theta - 6 \cos^4\theta$$

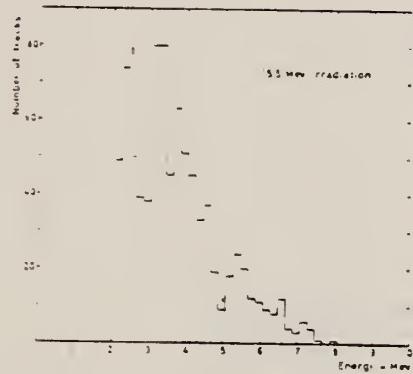


Fig. 3. The proton distribution from the 15.5 MeV irradiation after the background is subtracted.

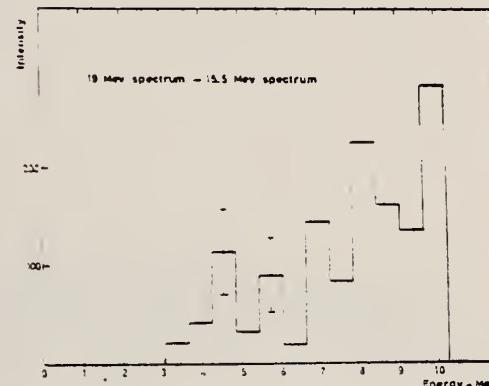


Fig. 5. The proton spectrum corresponding to photon absorption in the energy range 15.5-19 MeV.

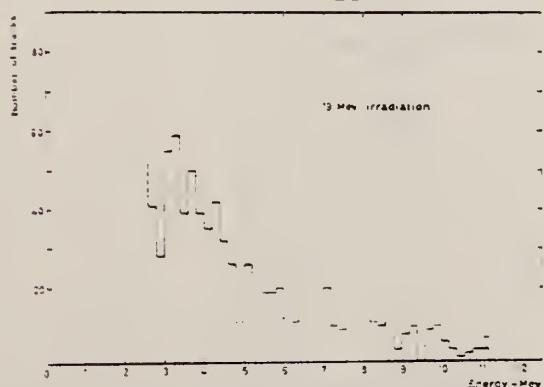


Fig. 4. The proton distribution from the 19 MeV irradiation after the background is subtracted.

Table 1. The reported resonances (MeV) in  $\text{F}^{19}$  obtained by photo-excitation. The column headings give the references and methods employed.

Taylor et al. [3]	Goldschmidt and Katz [4]	Benedek et al. [5]	Bertozzi et al. [6]	Lusch et al. [7]	Present work
%, p activation curve	%, n neutron-yield curve	%, n activation curve	%, n time of flight	%, p nuclear emulsion	%, p nuclear emulsion
			10.47		10.4
10.6	—	—			—
10.9	11.0	—			—
11.2		—			
11.5	11.5		11.5	11.1	11.4
11.9	11.4	12.0	12.0	12.0	11.9
12.2	—	—	—	—	
		—	—	—	12.8
		—	13.5	13.2	13.6
		—	14.4		
		—	15.5		15.4
		—			16.5
		—			18.1
13.3	13.3				

CLEM. S.I.M.	F	19	9
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METHOD

REF. NO.

60 Fo 2

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	

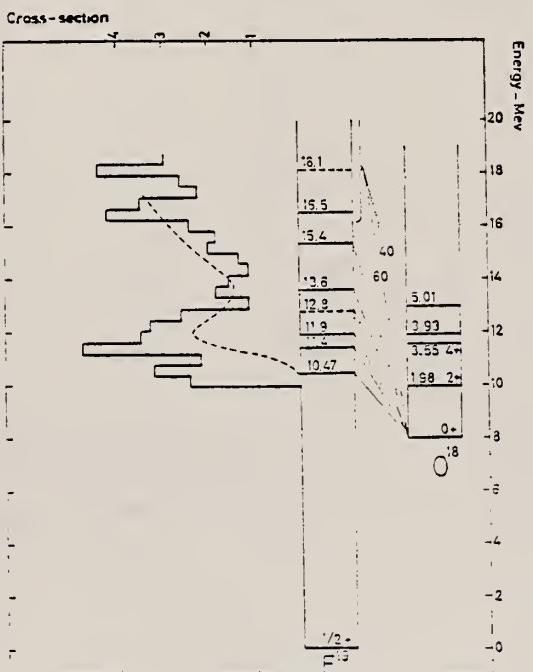


Fig. 7. The level scheme for the photo-disintegration of  $\text{F}^{19}$ . The histogram to the left gives the cross-section for  $(\gamma, \mu)$  in arbitrary units. The dotted curve shows the  $(\gamma, n)$  cross-section from 0 to 20 MeV in millibarns. The numbers for some of the transitions to  $\text{O}^{18}$  denote the relative branching ratio in per cent.

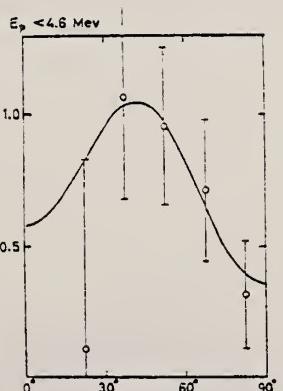


Fig. 8. The angular distribution of the protons with energies less than 4.6 MeV from the 15.5 MeV irradiation with thick teflon target.

Elem. Sym.	A	Z
F	19	9

Method

25 MeV Betatron; activation of Teflon; NaI counters for annih. rad.  
 of positions from residual nuclei.

Ref. No.

60 Ge 2

JHH

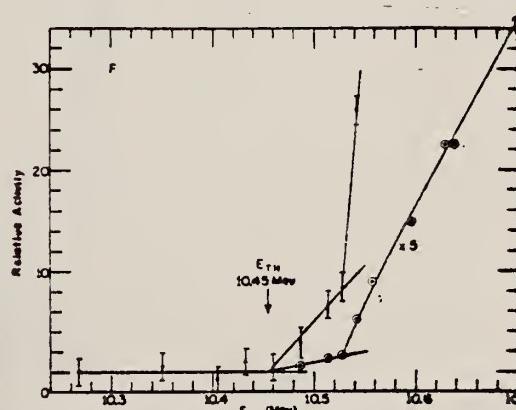
Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$(\gamma, n)$	10.27 - 10.7					<p><math>E_\gamma</math> (threshold) = <math>10.45 \pm 0.03</math> MeV          to be compared with Everling's neutrc separation energy <math>10.442 \pm 0.007</math> MeV from mass data.</p> <p>Observed break in yield curve (Figure 4) at: 10.53 MeV</p> 

FIG. 4. Activation curve for the reaction  $F^{19}(\gamma, n)F^{18}$ .

METHOD Betatron; neutron cross section; activity; Cu <sup>63</sup> ( $\gamma$ , n)					REF. NO.		
					60 Ki 4	NVB	
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N	ABX	10-23 (10.4-23.0)	C	10-23 (10.4-23.0)	ACT-I		4PI

Peaks at:

$$E_{\gamma} = 10.6 \text{ MeV (very small)}$$

12.4 MeV

14.0 MeV

16.1 MeV

17.2 MeV

19.3 MeV

666

Peaks at 14.0 and 19.3 MeV suggest split giant resonance, give quadrupole moment

$$Q_0 = 0.30 \times 10^{-24} \text{ cm}^2$$

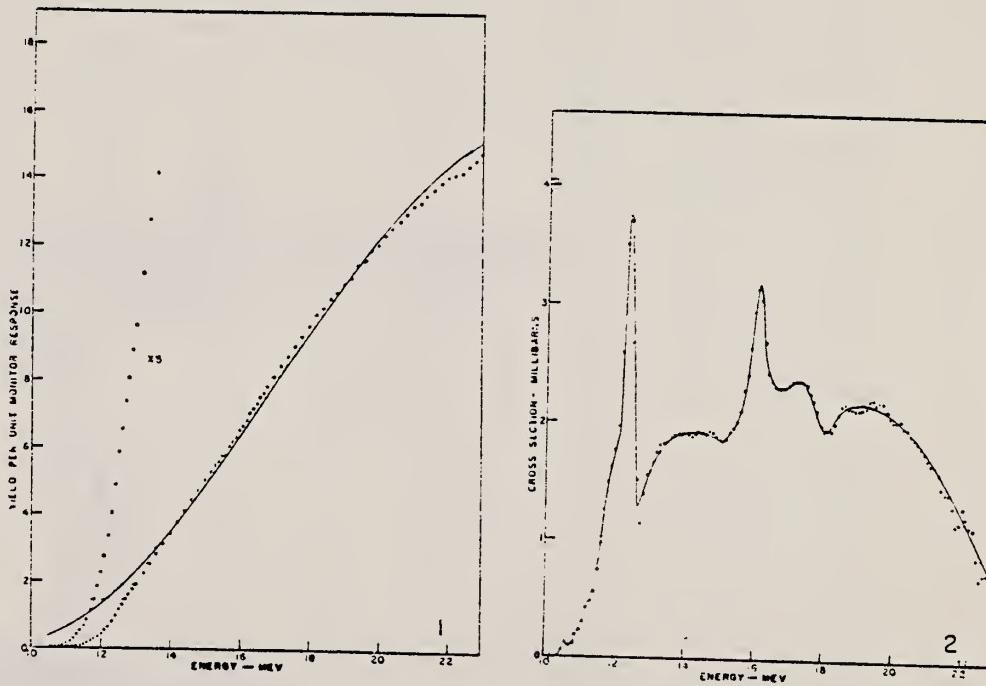


FIG. 1. Yield of Fe<sup>57</sup> per unit monitor response as a function of the maximum energy in the X-ray spectrum. The full curve is an analytic function of the form  $y = a[1 + \sin b(E - c)]$ .  
 FIG. 2. The cross section for Fe<sup>57</sup>( $\gamma$ , n)Fe<sup>57</sup> obtained from the smoothed yield curve.

Elem. Sym.	A	Z
F	19	9

Method

$\gamma$ 's from  $F^{19}(\gamma, \alpha\gamma)$  reaction; protons from Van de Graaff; NaI

Ref. No.

60 Re 1

JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$F^{19}(\gamma, \gamma)$	$\sim 7$					$\langle \bar{\sigma} \rangle (E_p = 2.05 \text{ MeV}) = < 0.03 \text{ mb}$ Assuming dipole transitions.

METHOD					REF. NO.		
Betatron; neutron yield; activity; ion chamber					60 Sa 2		NVB
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N	RLY	10 - 12	C	10 - 12	ACT-I		4PI

Breaks in activation curves:

10.40 MeV

10.45 MeV

10.71 MeV

10.86 MeV

11.06 MeV

11.18 MeV

11.38 MeV

11.57 MeV

11.84 MeV

12.09 MeV

REF.

T.G. Walker, W.T. Morton  
 Proc. Phys. Soc. 75, 4 (1960)

ELEM. SYM.

F

19

9

## METHOD

Synchrotron; neutron cross section; radioactivity

REF. NO.

60 Wa 2

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N	ABX	10-240	C	120-240 (120, 180, 240)	ACT-I		4PI

$$\sigma = (3.5 \pm 0.3) 10^{-27} \text{ cm}^2/\text{equivalent quantum}$$

Data below 120 MeV from other workers; 50 MeV data is that of Barber et al, Phys. Rev. 98, 73 (1955).

Maximum bremsstrahlung energy (MeV)	Yield of $^{18}\text{F}$ from			$^{18}\text{C}(\gamma, n)^{14}\text{C}$ yield
	$^{18}\text{F}$	$^{22}\text{Na}$	$^{27}\text{Al}$	
240	1.83(17)	0.18(9)	0.062(13)	1.62
180	1.78(16)	0.18(16)	0.058(16)	1.50
120	1.6(14)	0.15(14)	0.045(14)	1.34
100	1.5	—	—	1.27
70	1.4	0.11	—	1.15
50	1.22	0.07	—	1.0

	Elem. Sym.	A	Z
	F	19	9

Method 4 MeV-electron Van de Graaff; brems.; nuclear resonance scattering, ring scatterer; NaI

Ref. No.  
 62 Bo 6 JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$F^{19} (\gamma, \gamma)$	Bremss. 0 - 4					

TABLE 3  
 Mean lifetimes of excited states deduced from the resonance scattering of bremsstrahlung

Nucleus	%	Energy (MeV)	Spins	$g$	$\Gamma_a/\Gamma$	$W'(\theta)$	$\tau \times 10^{10} \pm 35\%$ (sec)
F <sup>19</sup>	100	1.46	$\frac{1}{2}^+$ -?	?	0.13	(1)	0.25 $\mu$
Na <sup>22</sup>	100	2.08	$\frac{1}{2}^+ - \frac{3}{2}^-$	2	0.1	0.79	>0.04
		2.39	-?	?	0.53	(1)	>1.6 $\mu$
		2.64	-?	?	0.6	(1)	>0.3 $\mu$
		2.70	-?	?	(0.1)	(1)	>0.008 $\mu$
		2.98	-?	?	0.46	(1)	0.03 $\mu$
Al <sup>27</sup>	100	2.73	$\frac{3}{2}^+ - \frac{3}{2}^+$	1	$\leq 0.3$	0.91	>0.2 $\mu$
		2.98	-?	?	0.216	1	$2.2 \times 10^{-4}$
Si <sup>28</sup>	4.71	1.23	$\frac{1}{2}^+ - \frac{3}{2}^+$	2	1	0.38	1.5
		2.43	-?	2	(1)	0.33	0.3
P <sup>31</sup>	100	1.26	$\frac{1}{2}^+ - \frac{1}{2}^+$	2	1	0.38	2.2
		2.23	-?	3	1	0.79	4.5
		3.13	-?	2	(1)	0.88	0.2
		3.29	-?	3	?	0.79	$>1.8(\Gamma_a/\Gamma)^2$
		3.41	-?	?	?	(1)	$>1.3g(\Gamma_a/\Gamma)^2$
		3.51	-?	2	?	0.83	$0.02(\Gamma_a/\Gamma)^2$
S <sup>32</sup>	95	3.78	0 <sup>+</sup> -2	?	?	(1)	$>0.6g(\Gamma_a/\Gamma)^2$
S <sup>34</sup>	4.2	2.127	0 <sup>+-</sup> -2	5	1	0.63	>1.0
Cl <sup>35</sup>	75.5	1.22	$\frac{1}{2}^+ - \frac{3}{2}^+$	?	1	(1)	6 $\mu$
		1.76	-?	?	(1)	(1)	4 $\mu$
		2.7(2.65)	-?	?	?	(1)	$0.31g(\Gamma_a/\Gamma)^2$
		3.01	-?	?	?	(1)	$0.37g(\Gamma_a/\Gamma)^2$
Cl <sup>36</sup>	75.5	3.1	-?	?	?	(1)	$>0.74g(\Gamma_a/\Gamma)^2$
		3.17	-?	?	?	(1)	$>1.3g(\Gamma_a/\Gamma)^2$
Cl <sup>37</sup>	24.5	0.838	$\frac{3}{2}^+ - \frac{3}{2}^+$	?	1	(1)	>13 $\mu$
		1.72	-?	?	?	(1)	$>0.5g(\Gamma_a/\Gamma)^2$
K <sup>39</sup>	93	2.53	$\frac{3}{2}^+ - \frac{3}{2}^+$	?	1	(1)	>1.6 $\mu$
		2.82	-?	?	1	(1)	>1.3 $\mu$
		3.02	-?	?	1	(1)	0.37 $\mu$
		3.60	-?	?	1	(1)	>0.7 $\mu$
		3.88(3.94)	-?	?	?	(1)	$0.14g(\Gamma_a/\Gamma)^2$
		4.06-4.12	-?	?	?	(1)	$>0.2g(\Gamma_a/\Gamma)^2$
Ca <sup>40</sup>	96	3.99	0 <sup>+-</sup> -2 <sup>+</sup>	5	1	0.63	>0.46
Cu <sup>63</sup>	69	1.33	$\frac{3}{2}^+ - \frac{3}{2}^-$	2	(1)	0.8	$44 > \tau > 11$

The factor  $g$  equals  $(2I+1)(2I_0+1)^{-1}$ .

METHOD Van de Graaff; proton spectrum, angular distribution; nuclear emulsion					REF. NO. 62 Br 3	NVB	
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, P	SPC	18	D	18	EMU-D	2-10	DST
		(17.6)		(17.6)			

In Figure 5,  $W(\theta) = a + b \sin^2 \theta$

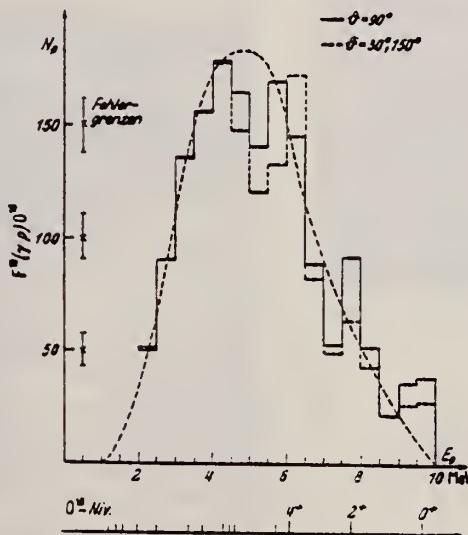


Fig. 4. Energieverteilung der Photoprotonen aus Fluor. Gestrichelte Kurve: Verteilung nach der statistischen Theorie, Stufenkurven: gemessenes Spektrum für  $\theta = 90^\circ$  bzw. Mittelwert der Spektren für  $\theta = 30^\circ, 150^\circ$ . Darunter: Niveauschema des Restkerns  $O^{18}$  (von rechts nach links)

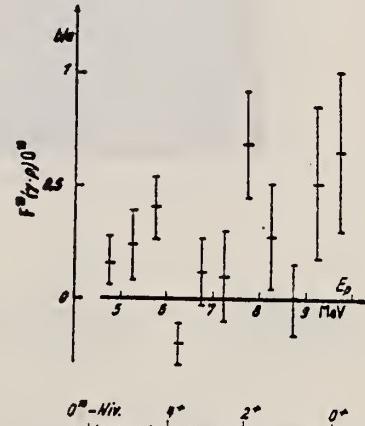


Fig. 5. Anisotropie-Faktor  $b/a$  in Abhängigkeit von der Protonenergie mit statistischem Fehler, darunter Niveaus des Restkerns  $O^{18}$

Elem. Sym.	A	Z
F	19	9

Method Electrostatic gun  $H^3(p,\gamma)He^4$  reaction; activation of positron emitter; 2 coincidence.

Ref. No.  
664

JHH

Reaction	E or $\Delta E$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes	664
$(\gamma, n)$	20.2-21.1				$\sigma(\gamma, n) = 3.30 \pm 0.41 \text{ mb}$ at 20.48 MeV. Teflon sample. Fluctuations in Figure 7 may be due, in part, to carbon correction [10-50% of total $\sigma(\gamma, n)$ ].	

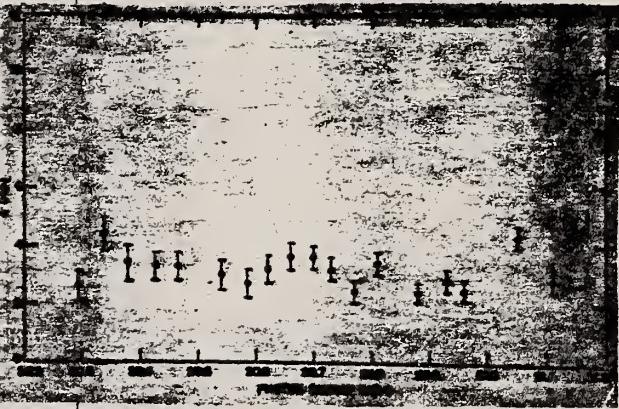


Figure 7: The  $F^{19}(\gamma, n)F^{18}$  reaction cross section in millibarns as a function of photon energy in MeV.

Elem. Sym.	A	Z
F	19	9

Method

Magnetic analysis of proton spectrum produced by electron bombardment

Ref. No.

62Dol

BG

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes	803
(e,p)	18, 24.5 30	3.25 3.7 4.5 7.3 10.1		$29^{+9}_{-3} 23$ 10.5	*	For ground state transition $E_\gamma =$ 11.42 11.90 12.74 15.70 18.70  *Calculated assuming 100% ground state transitions.  Correspondence between (e, $p\epsilon'$ ) reaction and ( $\gamma$ , p) reaction; assumed electron has associated with it a virtual photon spectrum. Electron production yields analyzed by use of E1 virtual photon spectrum to obtain $\sigma(\gamma, p)$ .  Angular distribution measured; assume to be of form $A' + B' \cos\theta + C' \sin\theta + \dots$	

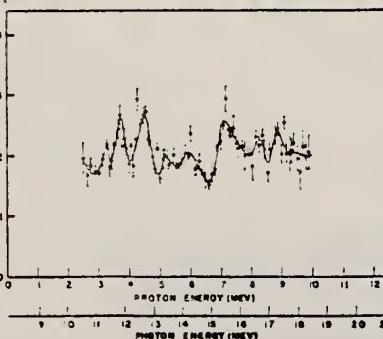
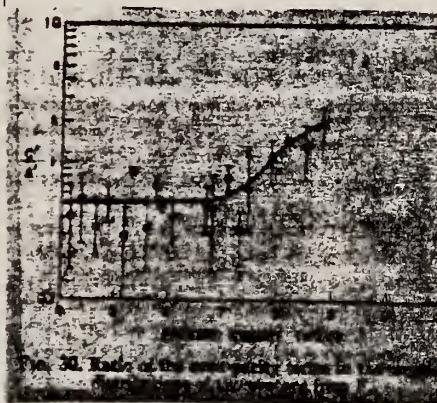
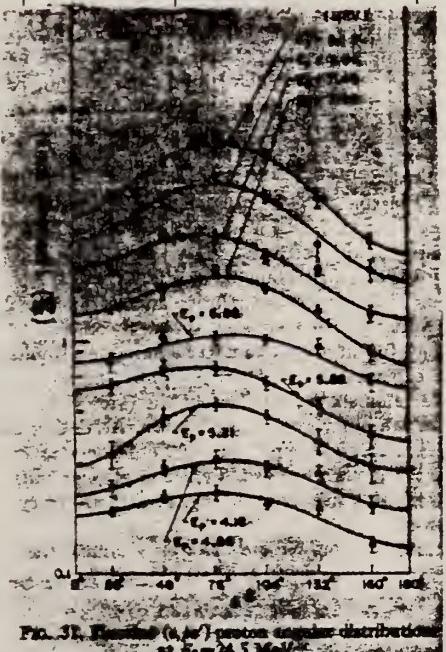


FIG. 12. Fluorine (e, p) cross sections for  $E_0 = 24.5$  MeV &  $\Gamma = 23$ , under the assumption that  $\gamma$ 's ground-state transitions (shown to be erroneous).

Elem. Sym.	A	Z
F	19	9

Method:

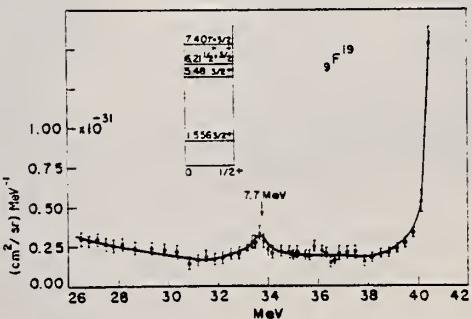
Lines (Stanford Mark IX) - counter telescope

Ref. No.

63Bal

83

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
(e,e')	41.5	7.7	4.7	0.54		<p>Differential scattering cross section at <math>180^\circ</math> = <math>2.0 \pm 25\% \times 10^{-32} \text{ cm}^2/\text{sr}</math></p> <p>Rad. width corresponds to transition from <math>\frac{1}{2}^+</math> ground state to <math>\frac{3}{2}^+</math> excited state.</p>

Fig. 9. Spectrum of 41.5 MeV electrons scattered from  $\text{CF}_3$  at  $180^\circ$ .

Elem. Sym.	A	Z
F	19	9

Method

24 MeV betatron; proton spectrum; silicon-diode charged particle detector; r-chamber

Ref. No.  
63 Mu 1

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
( $\gamma$ , p)	Bremss. 23.5					On basis of spectrum measured with absorber concludes there are some heavy charged particles present. Detector at 120°.

TABLE II. Proton energies and  $F^{18}$  levels, in MeV.

$E_p$	F <sup>18</sup> to O <sup>16</sup> ground state			Other
	Dodge <sup>a</sup> (e, ps)	Fork- man <sup>b</sup> ( $\gamma, n$ )	Other <sup>c</sup> ( $\gamma, p$ )	
(2.98)				
$3.58 \pm 0.06$	11.80	15.44 to 3.63	11.42	11.4
$4.28 \pm 0.06$	12.55		11.90	11.9
(4.97)			12.74	12.8
$5.83 \pm 0.06$	14.19		13.6	
(6.23)		(16.60 to 1.98)		
$6.97 \pm 0.05$	15.41		15.4	15.3 <sup>d</sup>
(7.53)			15.70	
$8.10 \pm 0.08$	16.61		16.5	
(8.65)				

<sup>a</sup> See Ref. 11.

<sup>b</sup> See Ref. 7.

<sup>c</sup> See Ref. 3.

<sup>d</sup> See Ref. 3.

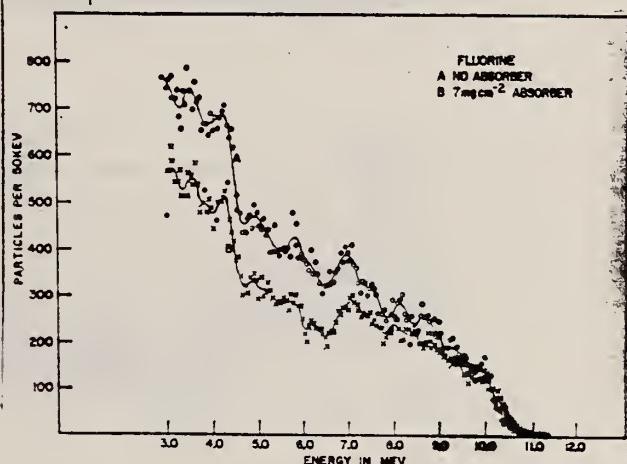


FIG. 7. Pulse-height distributions from fluorine. Curve A represents the smoothed value of data taken with no absorber. Curve B represents the smoothed value of data taken with  $7 \text{ mg cm}^{-2}$  of aluminum between target and detector, and was corrected in the same manner as in Fig. 5.

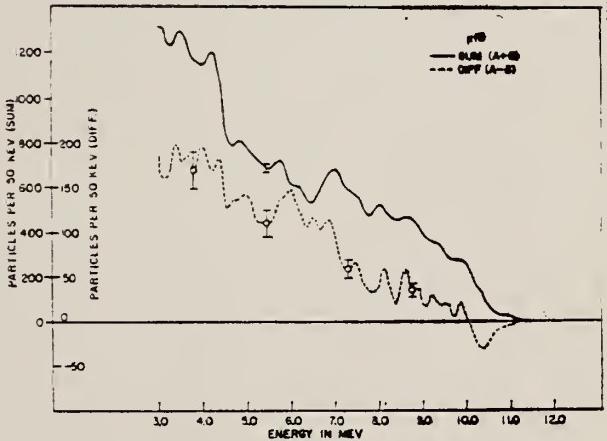


FIG. 8. The continuous curve represents the sum of curves A and B of Fig. 7, plotted against the same energy at the left. The dashed curve is the difference (A-B), plotted against the inner scale.

ELEM. SYM.	A	Z
F	19	9

METHOD

Van de Graaff; resonance fluorescence

REF. NO.

64 Bo 1 NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, G	LFT	1-3 (0.5 - 3.0)	C	1 - 3 (0.5 - 3.0)	NAI-D		100

ABI

TABLE I  
 Cases of observed resonance fluorescence

Nucleus multipol.	State (MeV)	Spin	$\Gamma_0/\Gamma$	$T(g_w \Gamma_0^2/\Gamma^2)^{-1}$ (sec.)	Mean lifetime $T$ BCW (sec)	Mean lifetime $T$ other (sec)	Ref.	$\Gamma_0/\Gamma_w$ BCW
E1*	0.00	$\frac{1}{2}^+$						
E1	1.46	$\frac{3}{2}^-$	0.15	$27 \pm 8 \times 10^{-14} \Gamma_0/\Gamma$	$6.2 \pm 2 \times 10^{-14}$	$5 \pm 1.5 \times 10^{-14}$	*	$1.1 \times 10^{-3}$
M1*)	1.56	$\frac{1}{2}^+$	(0.04)	$11 \pm 4 \times 10^{-14} \Gamma_0/\Gamma$	$20_{-8}^{+10} \times 10^{-14} \Gamma_0/\Gamma$	-	-	$1.5 \times 10^{-3}$

ELEM. SYM.	A	Z
F	19	9

## METHOD

Betatron

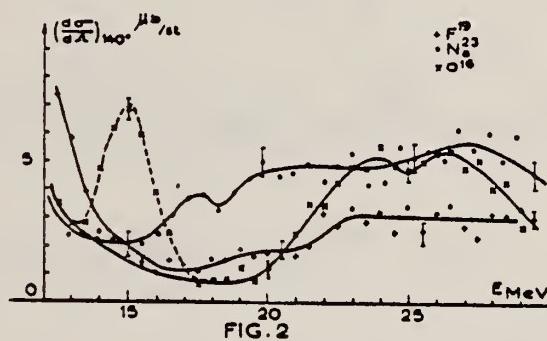
REF. NO.

64 Lo 3

JDM

REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE	RANGE		
G,G	ABX	10-30	C	10-30	NAI-D	140

The effective differential scattering cross section remains quite constant from 20-30 MeV.



METHOD	REF. NO.				
	64 Se 1 EGF				
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
G, XP	SPC	THR - 24	C 14-24	EMU-D 2-15	DST

Target thickness 3.4 mg/cm<sup>2</sup> and 5.7 mg/cm<sup>2</sup>.

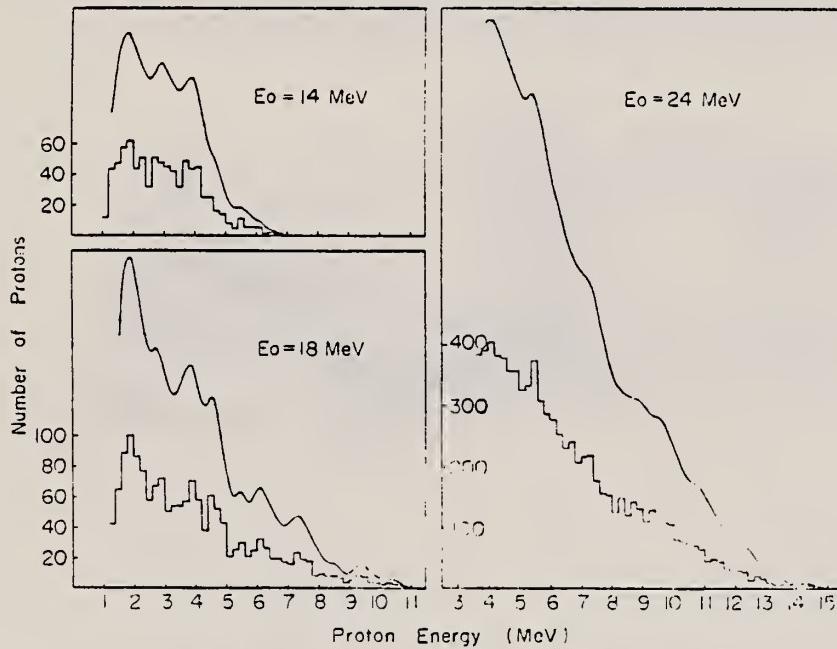


Fig. 2. Energy spectra of photoprottons from fluorine.

Table III. Coefficients  $a_i$ 's of the Expression (2).

$E_0$	Energy region (MeV)	$a_1$	$a_2$	$a_3$	$a_4$
18 MeV	$3.2 \leq E_p < 4.2$	0.45	-0.39	-0.32	-0.28
	$4.2 \leq E_p < 5.2$	0.78	0.55	-0.64	-1.31
	$5.2 \leq E_p < 10.0$	0.75	-0.65	-0.74	0.13
24 MeV	$8.0 \leq E_p < 10.0$	0.25	0.14	-0.27	-0.67
	$10.0 \leq E_p$	0.39	0.14	-0.27	-0.70

assuming an angular distribution of the form  
 $1 + a_1 \cos\theta + a_2 \cos^2\theta + a_3 \cos^3\theta + a_4 \cos^4\theta$ . (2)

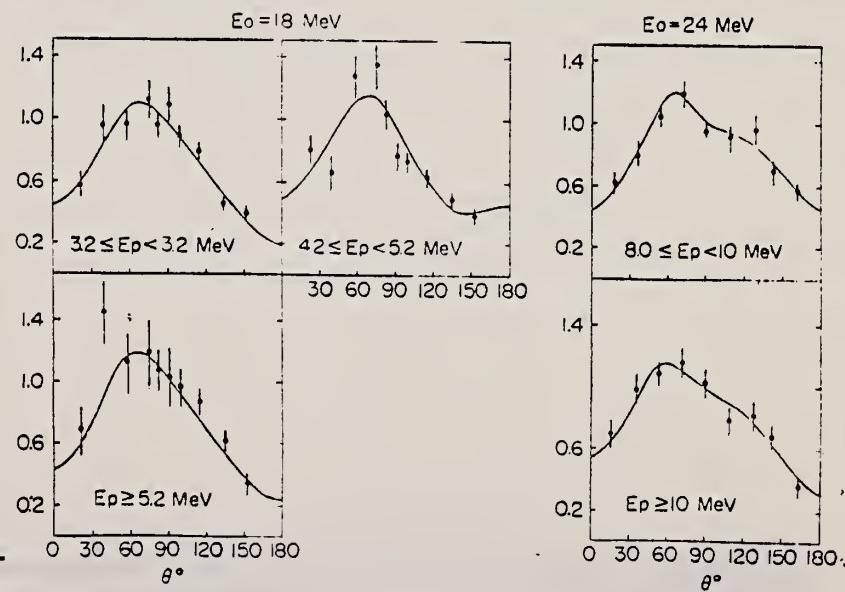


Fig. 4. Angular distributions of photoprottons from fluorine.

METHOD

Tandem,  $T^3(p,\gamma)$

REF. NO.

64 Te 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,MU-T	ABX	20-21	D	20-21	NAL-I		96

FIG. 10. Nuclear absorption cross section in  $F^{19}$  as a function of photon energy. The results of this experiment are plotted as dots. Other results are shown for comparison.

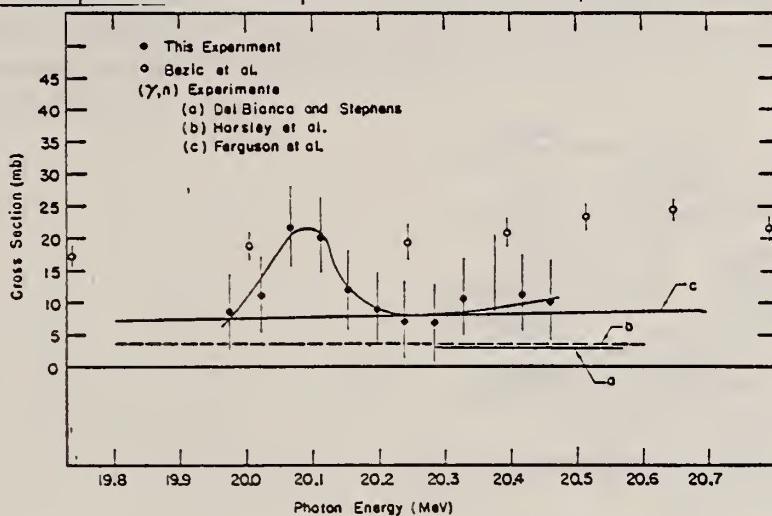


TABLE IV. Structure observed in the nuclear absorption cross section curves.

Element	$E_{peak}$ (MeV)	$\sigma_{peak}$ (mb)	Half-width (MeV)	$\int_{\text{peak}} \sigma dE$ (MeV-mb)
Be <sup>9</sup>	20.47	6.8	0.13	0.45
	20.73	10.1	0.15	0.9
O <sup>16</sup>	20.62	21.5	0.19	3.9
	21.02 <sup>{20.86}</sup> (21.05)	23.5	~0.40	10.4
$F^{19}$	>22 20.09	21.9	0.16	3.5

ELEM. SYM.	A	
F	19	9

METHOD

REF. NO.

65 Ha 2

JOC

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,A	SPC	THR-31	C	31	EMU-D	5-20	DST

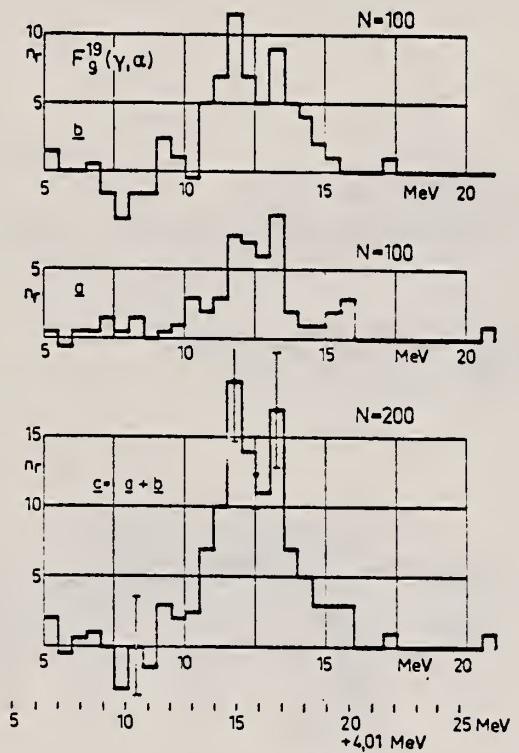


Fig. 8.

REF.

F.P. Denisov, A. Duisebaev, K.V. Kosareva, and P.A. Cerenkov  
 J. Nucl. Phys. (USSR) 1, 82 (1965)  
 Sov. J. Nucl. Phys. 2, 58 (1966)

ELEM. SYM.	A	Z
F	19	9

## METHOD

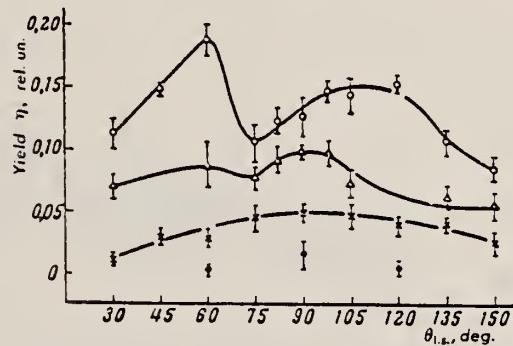
REF. NO.

Synchrotron; recoil nucleus method

66 De 5

JDM

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N	NOX	THR - 260	C	260	ACT-I		DST

Measured range of recoiling  $^{18}\text{F}$  nuclei.

Angular and energy distribution of the  $\text{F}^{18}$  recoil nuclei; the points on the curves correspond to the following pressures (in centimeters mercury): ○—pressure  $\sim 0$ ; △—3.3; ×—10; ●—15.

REF. B. S. Dolbilkin, V. A. Zapevalov, V. I. Korin, L. E. Lazareva  
and F. A. Nikolaev  
Izv. Akad. Nauk fiz. 30, 349 (1966)  
Bull. Acad. Sci. USSR-Phys. 30, 354 (1966)

ELEM. SYM.	A	Z
F	19	9

METHOD

REF. NO.

66 Do 2

EGF

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G-MU-T	ABX	8-30	C	260	MGP	6-30	4PI

Resolution 120 keV      10 MeV  
220 keV      20 MeV

417

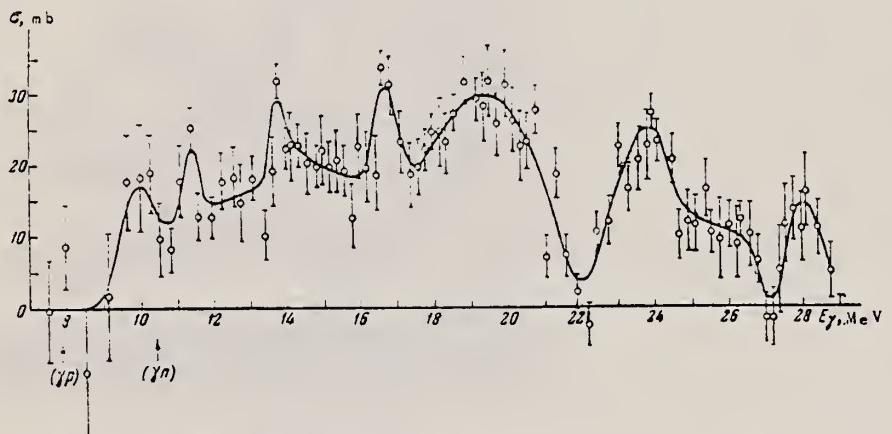


Fig.2. Nuclear absorption cross section of fluorine.

METHOD						REF. NO.	
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N	ABX	THR-25	C	THR-25	ACT-I		4PI

NSA 35223 BREAKS

35223 ON THE NUCLEAR SHAPE AND THE PHOTONEUTRON CROSS SECTION OF THE  $^{19}\text{F}$  NUCLEUS. Baciu, G.; Catana, D.; Deberth, C.; Raileanu, I. (Inst. of Atomic Physics, Bucharest). Rev. Roum. Phys., 12: 385-91(1967).

The absolute cross section for the ( $\gamma, n$ ) reaction on  $^{19}\text{F}$  was measured by using the bremsstrahlung of the IFA betatron with a maximum energy of 25 MeV. The induced radioactivity in the samples of  $\text{C}_2\text{F}_{5+\gamma}$  (teflon) was recorded by means of a  $\gamma-\gamma$  scintillation spectrometer. The data supplied by the spectrometer were recorded by a SA-40 type (intertechnique) multichannel analyzer. The yield points were taken at 0.25 MeV intervals. The betatron energy scale stability was controlled at least two times per day and a deviation smaller than  $\pm 10$  keV was observed. The calculated cross-section shows several discrete resonances; those disposed in the giant resonance region were well described by three Gaussians. The maxima occur at 15.10, 18.88, and 19.90 MeV. From the fine structure of the giant resonance the nucleon deformation parameters and the intrinsic quadrupole moment were calculated. They are:  $\gamma = 12^\circ$ ,  $\beta = 0.19$ , and  $Q_0 = 0.125$  barns. (auth)

ELEM. SYM.	A	Z
F	19	9

METHOD

REF. NO.	JOC
67 Lo 1	

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G/	ABX	14-32	C	34	NAI-D		DST

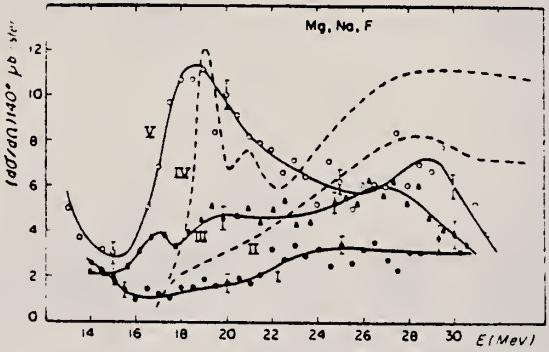


FIG. 6.

Sections efficaces différentielles de diffusion à 110° pour  $^{19}\text{F}$  (I),  $^{23}\text{Na}$  (III) et Mg (V).

Section efficace prévue par la relation de dispersion pour  $^{23}\text{Na}$  (courbe II) et Mg (courbe IV).

ELEM. SYM.	A	Z
F	19	9

## METHOD

REF. NO.

68 Ab 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XP	SPC	THR-22	C	22	SCD-D	3-13	90

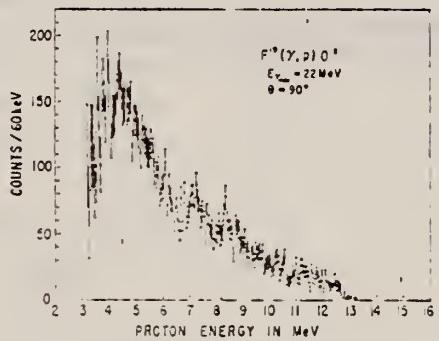


Fig. 2. Photoprotton spectrum from a polytetrafluoroethylene target.

METHOD	REF. NO.					
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE	RANGE	TYPE	RANGE
G,N	ABI	10- 50	C	10- 50	MOD-I	4PI
G,2N	ABI	25- 50	C	20- 50	MOD-I	4PI

$$\int_{TH}^{50} \sigma(\gamma, sn) dE = 221 \pm 20 \text{ MeV-mb.}$$

A 40" liquid scintillation detector was constructed for use in photonuclear work. Integrated cross sections for reactions in which one or two neutrons are emitted were measured up to 50 MeV for fluorine. The efficiency of the detector was about 60%.

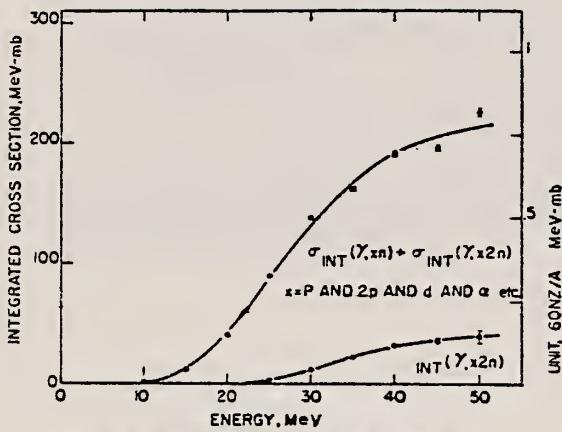


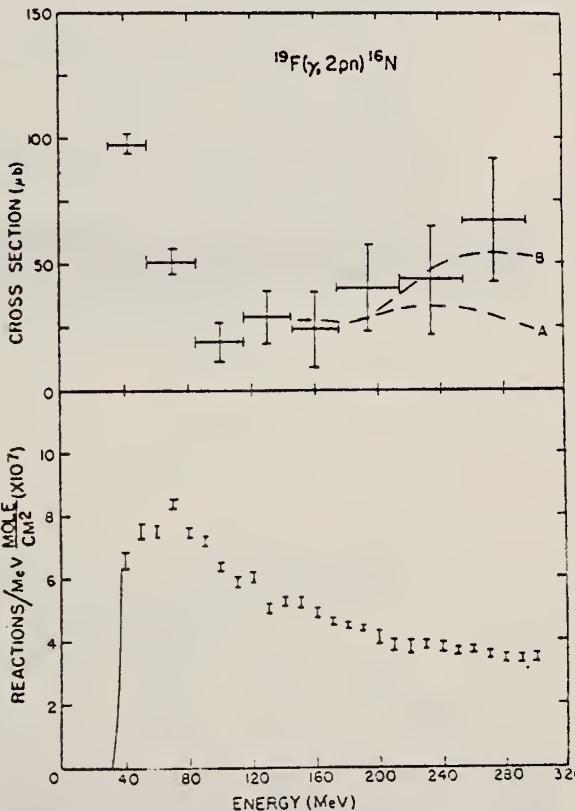
Fig. 9. Integrated cross sections for fluorine.

METHOD					REF. NO.		
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,2PN	ABX	THR-300	C	20-300	ACT-I		4PI

TABLE I  
 Summary of integrated cross sections  $\int_0^{E_{\max}} \sigma dE (\text{MeV} \cdot \text{mb})$  for the reactions studied

Reaction/ $E_{\max}$ (MeV)	65	105	145	215	295
$^{16}\text{O}(\gamma, 2n)^{14}\text{O}$	$0.42 \pm 0.02$	$0.57 \pm 0.04$	$0.56 \pm 0.05$	$0.63 \pm 0.09$	$1.29 \pm 0.16$
$^{19}\text{F}(\gamma, 2pn)^{16}\text{N}$	$3.7 \pm 0.2$	$5.0 \pm 0.3$	$6.1 \pm 0.5$	$8.4 \pm 1.0$	$13.6 \pm 1.5$
$^{27}\text{Al}(\gamma, 2pn)^{24}\text{Na}$	$8.3 \pm 0.3$	$13.3 \pm 0.7$	$17.1 \pm 1.2$	$24.1 \pm 2.3$	$31.2 \pm 3.3^a$
$^{54}\text{Mn}(\gamma, z)^{47}\text{Sc}$	$12.3 \pm 1.7$	$20.2 \pm 3.5$	$32.5 \pm 2.6$	$68.4 \pm 3.8$	$112 \pm 14$
$^{54}\text{Mn}(\gamma, z3n)^{40}\text{Sc}$	$0.7 \pm 0.2$	$6.0 \pm 0.9$	$12.2 \pm 1.3$	$34.1 \pm 4.1$	$91 \pm 11$

<sup>a</sup>)  $E_{\max} = 275$  MeV.



The dashed lines show the cross sections expected for quasi-deuteron processes (curve A) and the sum of the cross sections expected for quasi-deuteron and pion emission processes (curve B).

Fig. 2. Yields and cross sections for the  $^{19}\text{F}(\gamma, 2pn)^{16}\text{N}$  reaction. The solid line shows the assumed extrapolated yield curve behavior near the reaction threshold. The dashed lines have the same significance as in fig. 1.

ELEM. SYM.	A	Z
F	19	9

METHOD	REF. NO.
	69 Be 2 egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,MU-T	ABX	10-30	C	35	MGC-D	10-30	4PI

107

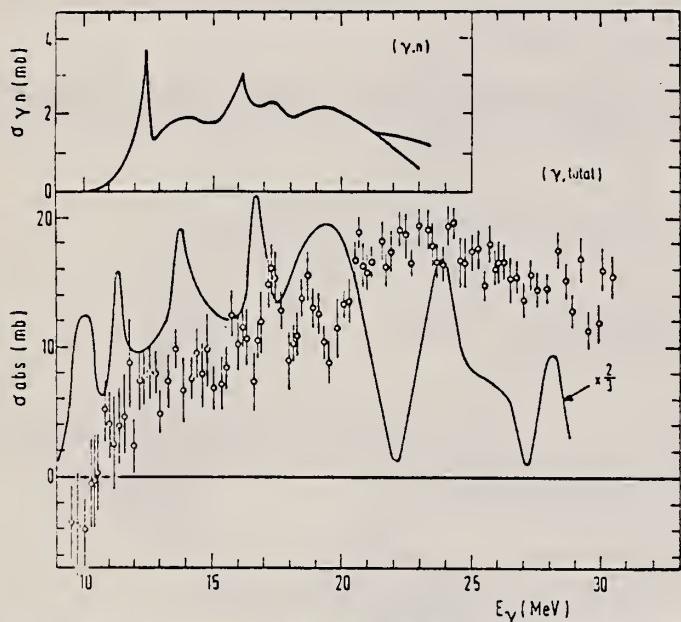


Fig. 4. The nuclear part of the photo-absorption cross section for  $^{19}\text{F}$ . The inaccuracy of the zero line position is estimated to be the same as in case of  $^{14}\text{N}$ . The solid line represents the photonuclear absorption cross section of Dolbilkin *et al.*<sup>7</sup>) multiplied by a factor of  $\frac{1}{3}$ . The  $(\gamma, \text{n})$  cross section<sup>25</sup>) is shown in the upper left corner.

TABLE I  
 Weighted energy-integrated total photonuclear cross sections

	$\sigma_{\text{int}}$ (mb · MeV)	$\sigma_{\text{int}}$ $60(NZ/A)$ (mb · MeV)	$\sigma_{-1}$ (mb)	$\sigma_{-1}$ $0.30A^{\frac{1}{2}}$ mb	$\sigma_{-2}$ (mb · MeV $^{-1}$ )	$\sigma_{-2}$ $3.5A^{\frac{1}{2}}$ (μb · MeV $^{-1}$ )
$^{12}\text{C}$	$133 \pm 13$	$0.74 \pm 0.07$	$5.4 \pm 0.6$	$0.65 \pm 0.07$	$0.23 \pm 0.03$	$1.04 \pm 0.15$
$^{14}\text{N}$	$195 \pm 37$	$0.93 \pm 0.08$	$8.4 \pm 1.7$	$0.83 \pm 0.20$	$0.36 \pm 0.08$	$1.28 \pm 0.29$
$^{16}\text{O}$	$171 \pm 17$	$0.71 \pm 0.07$	$7.2 \pm 0.8$	$0.60 \pm 0.07$	$0.31 \pm 0.04$	$0.87 \pm 0.11$
$^{18}\text{F}$	$271 \pm 50$	$0.94 \pm 0.17$	$14.1 \pm 2.7$	$0.82 \pm 0.19$	$0.74 \pm 0.17$	$1.60 \pm 0.35$
$^{20}\text{Si}$	$360 \pm 30$	$0.86 \pm 0.07$	$17.5 \pm 1.7$	$0.68 \pm 0.07$	$0.83 \pm 0.10$	$0.93 \pm 0.11$
$^{40}\text{Ca}$	$580 \pm 60$	$0.96 \pm 0.10$	$29 \pm 3$	$0.71 \pm 0.08$	$1.5 \pm 0.2$	$0.92 \pm 0.12$

The interval of integration is 10-30 MeV.

<sup>7</sup>B.S. Dolbilkin, V.A. Zapevalov, V.I. Korin, L.E. Lazareva and F.A. Nikolaev, Izv. Akad. Nauk SSSR (ser. fiz.) 30 (1966) 349.

<sup>25</sup>J.D. King, R.N. Haslam and W.J. McDonald, Can. J. Phys. 38 (1960) 1069.

ELEM. SYM.	A		
F	19	9	
REF. NO.			
70 Wa 1			egf

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE	RANGE	
E, E/	LFT	1-2	D	30-60	MAG-D
					28-60
					DST

Tabelle 2. Ergebnisse

1.56, 1.35 MEV

$E_x$ (MeV)	$\Gamma_\gamma^0$ (eV)	$\Gamma_\gamma^0/\Gamma_W$	$B(q=0)$	$R_{tr}$ (fm)
1,56 (E2)	$(1,76 \pm 0,15) \cdot 10^{-4}$	$7,65 \pm 0,61$	$(47,2 \pm 4,0) \text{ fm}^4$	$3,94 \pm 0,34$
1,35 (E3)	$(8,1 \pm 1,7) \cdot 10^{-10}$	$12,0 \pm 2,4$	$(795 \pm 160) \text{ fm}^6$	(4,2) vorgegeben

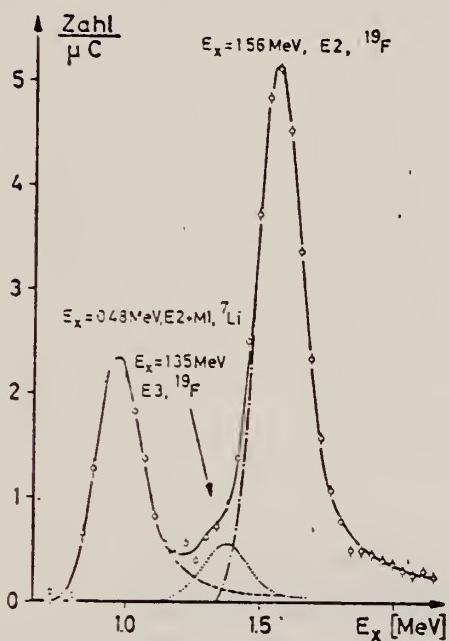


Fig. 1. Spektrum der unelastisch gestreuten Elektronen an LiF bei  $E_0 = 58,0$  MeV und  $\theta = 117^\circ$ ; Abszisse: Anregungsenergie im  $^{19}\text{F}$ . Die Strahlungsschwänze der elastischen Linien sind abgezogen. Die gestrichelte, die punktierte und die strichpunktierte Kurve zeigen die Anteile aus der angepaßte, durchgezogene Kurve zusammengesetzt ist

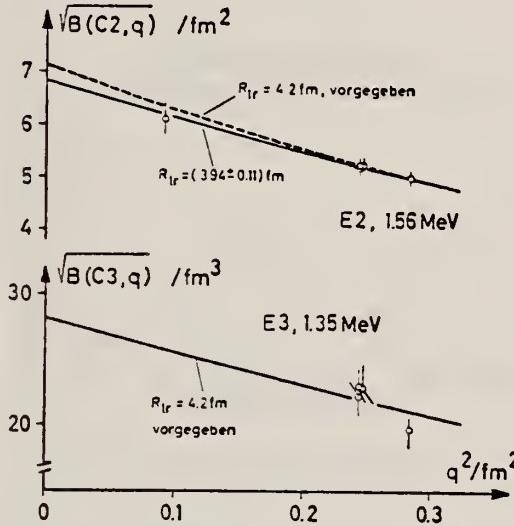


Fig. 2. Die reduzierten Übergangswahrscheinlichkeiten  $B(C_2, q)$  und  $B(C_3, q)$  als Funktion von  $q^2$

Tabelle 1. Experimentelle Daten  
Der Korrekturfaktor der DWBA-Analyse ist wie folgt definiert:  $f_c(q, E_0, E_x) = (d\sigma/d\Omega)_{\text{DWBA}}/(d\sigma/d\Omega)_{\text{BA}}$

$E_0$ (MeV)	$\theta$	E2, $E_x = 1,56$ MeV					E3, $E_x = 1,35$ MeV				
		$q^2$ ( $\text{fm}^{-2}$ )	$\sigma/\sigma_E$ ( $10^{-3}$ )	Fehler (%)	$d\sigma/d\Omega$ ( $10^{-6} \text{ fm}^2/\text{ster}$ )	$f_c$	$q^2$ ( $\text{fm}^{-2}$ )	$\sigma/\sigma_E$ ( $10^{-3}$ )	Fehler (%)	$d\sigma/d\Omega$ ( $10^{-7} \text{ fm}^2/\text{ster}$ )	$f_c$
57,99	117°	0,243	2,37	5,2	7,94	1,106	0,244	2,26	17,4	7,59	1,176
57,99	117°	0,243	2,35	5,1	7,87	1,106	0,244	2,45	15,5	8,21	1,176
58,29	117°	0,246	2,36	5,3	7,73	1,106	0,247	2,43	19,2	8,06	1,176
59,06	129°	0,283	3,26	5,0	5,02	1,097	0,284	3,17	17,7	4,88	1,162
36,01	117°	0,092	0,30	14,7	4,18	1,155	—	—	—	—	—

	Punched	Checked w/PO
IBM Card	7/1/70	9/10/70
DATA		
IBM Card	7/9/70	9/10/70
REFERENCE		

METHOD				REF. NO.		
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE	RANGE		
G,N	ABX	12-15 (12.3-14.5)	C	15	TOF-D	135

662

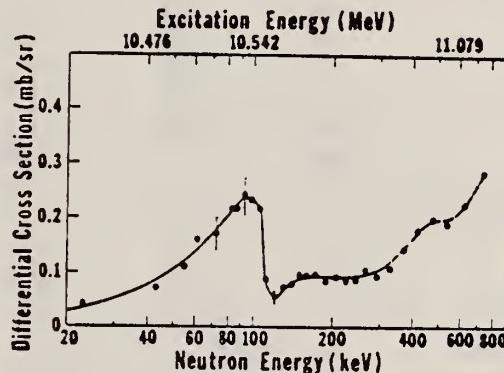


FIG. 18. The 135° differential threshold photo-neutron cross section for  $^{19}\text{F}$  (see caption to Fig. 4).

FIG. 4. The 135° differential threshold photoneutron cross section for  $^{207}\text{Pb}$  at low energies versus the energy of the emitted neutron (lower scale) and the excitation energy (upper scale). The arrows indicate peaks which decay to excited states of the residual nucleus (ES), or peaks owing to contaminating isotopes in the photoneutron sample. The inset shows the  $^{207}\text{Pb}(\gamma, \pi)$  cross section averaged with a square 40-keV wide smoothing function.

Also see:

R. J. Baglan et al.,  
Phys. Rev. C3, 2475  
(1971)

[over]

TABLE VII. Resonance parameters for  $^{24,25,26}\text{Mg}$ ,  $^{19}\text{F}$ , and  $^{31}\text{P}$ . For all resonances, the area under the peak in the 135° differential cross section is multiplied by  $4\pi$  to yield approximate values for  $g_\gamma \Gamma_{\gamma 0} \Gamma_n / \Gamma \approx g_\gamma \Gamma_{\gamma 0}$ . For those resonances where  $J''$  is known, the differential area is multiplied by the appropriate factor  $F$  from Table I to obtain  $\Gamma_{\gamma 0}$ .  $E_L$  is the laboratory neutron energy for the  $(\gamma, n)$  reaction and  $E_n$  is the corresponding laboratory neutron energy for a neutron-induced reaction. Column 5 labels the peak as a ground-state (GS) or excited-state (ES) transition as determined in this work alone.

Nucleus	$E_L$ (keV)	$E_{ex}$ (MeV)	$g_\gamma \Gamma_{\gamma 0} \Gamma_n / \Gamma$ (eV)	GS or ES	$J''$	$\Gamma_{\gamma 0}$ (eV)	$E_n$ (keV) (This work)
$^{24}\text{Mg}$	22	16.559	0.61		(1 <sup>-</sup> )	0.40	28
	55	16.596	2.4	GS	(1 <sup>-</sup> )	1.6	66
	110	16.656	4.0	GS	(1 <sup>-</sup> )	2.7	128
	312	16.871	10.7		(1 <sup>-</sup> )	7.1 <sup>a</sup>	354
	382	16.95					432
	717	17.30	19.5		(1 <sup>-</sup> )	13.0 <sup>a</sup>	804
	1210	17.83					1348
	1620	18.26					1799
	1955	18.61					2168
							46.8
$^{25}\text{Mg}$	41.1	7.374	0.09	GS			
	45.1	8.746	0.31	ES			
	74.9	7.410	0.36	GS	$\frac{3}{2}^-$ <sup>b</sup>	1.1	84.1 <sup>b</sup>
	208	8.920	0.29	ES			
	236	7.580	0.09	GS			
	404	7.756	0.03				261
	439	7.793	0.05		$\frac{5}{2}^+$ <sup>c</sup>		445
	472	7.828	0.06				484
	515	7.873	0.46	GS	$\frac{3}{2}^+$ <sup>c</sup>		520
	601	7.964	0.18				567
	781	8.152	1.51	GS			661
	912	8.292	0.72				857
	1236	9.999	2.4 <sup>c</sup>	ES	$\frac{3}{2}^+$ or $\frac{5}{2}^+$ <sup>c</sup>		1003
	1707	9.12					1869
	1764	9.18					1931
$^{26}\text{Mg}$	54.3	11.155	2.6	GS	1 <sup>-</sup> (1 <sup>+</sup> , 2 <sup>+</sup> )	1.75	62.3
	63.2	11.164	0.05			0.034	72.2
	181	11.289	1.0	GS	1 <sup>-</sup> (1 <sup>+</sup> , 2 <sup>+</sup> )	0.68	202
	222	11.333	1.9	GS	1 <sup>-</sup> (1 <sup>+</sup> , 2 <sup>+</sup> )	1.3	248
	391	11.511	5.1	GS	1 <sup>-</sup> (1 <sup>+</sup> , 2 <sup>+</sup> )	3.5	433
	621	11.753	32.5	GS	1 <sup>-</sup> (1 <sup>+</sup> , 2 <sup>+</sup> )	22.2	684
	738		15.0 <sup>d</sup>	ES		5.1	
	1122	12.279	14.7	GS	1 <sup>-</sup> (1 <sup>+</sup> , 2 <sup>+</sup> )	10.0	1232
$^{19}\text{F}$	100	10.542	1.8	GS			118
$^{31}\text{P}$	109	12.429	0.86				121
	280	12.609	0.60				307
	398	12.732	0.59				434
	678	13.026	0.90				737
	939	13.297	4.4				1013

<sup>a</sup>These values for  $\Gamma_{\gamma 0}$ , when increased by approximately a factor of 2 in order to include the relatively high cross sections in the valleys, agree very well with corresponding values from Ref. 8 (see Ref. 4).

<sup>b</sup>This resonance was seen at  $E_n = 83$  and 84 keV in Refs. 24 and 25, respectively.

<sup>c</sup>Analogs of states in  $^{23}\text{Na}$  (see text). The value for  $g_\gamma \Gamma_{\gamma 0} \Gamma_n / \Gamma$  given in Ref. 26 was not corrected with the multiplicative factor in Table II.

<sup>d</sup>Assuming a first-excited-state transition.

<sup>4</sup>R.L. Van Hemert, C.D. Bowman, R.J. Baglan, and B.L. Berman (to be published); R.L. Van Hemert, University of California Lawrence Radiation Laboratory Report No. UCRL-50442, 1968 (unpublished).

<sup>3</sup>S.C. Fultz, M.A. Kelly, J.T. Caldwell, R.R. Harvey, and B.L. Berman, Bull. Am. Phys. Soc. 14, 103 (1969), and private communication.

<sup>24</sup>H.W. Newson, R.C. Block, P.F. Nichols, A. Taylor, A.K. Furr, and E. Merzbacher, Ann. Phys. (N.Y.) 8, 211 (1959).

<sup>25</sup>D.J. Hughes and R.B. Schwartz, Neutron Cross Sections (U.S. Government Printing Office, Washington, D.C., 1966), 2nd ed., 2nd Suppl., Vol. IIc.

METHOD

REF. NO.

71 Di 5

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N	ABY	10-999	C	300-999	ACT-I		4PI

The use of the  $^{19}\text{F}(\gamma, n)^{18}\text{F}$ ,  $^{27}\text{Al}(\gamma, x)^{24}\text{Na}$ ,  $^{197}\text{Au}(\gamma, n)^{196}\text{Au}$ , and  $^{12}\text{C}(\gamma, x)^{7}\text{Be}$  reactions as absolute monitors for high-energy, high-intensity bremsstrahlung beams is discussed. The cross sections per equivalent quantum and the absolute cross sections, in the energy range 300-1000 MeV, are reported for these reactions.

999 = 1 GEV

$^{19}\text{F}(\gamma, n)^{18}\text{F}$ ,  $^{27}\text{Al}(\gamma, x)^{24}\text{Na}$ , and  $^{12}\text{C}(\gamma, x)^{7}\text{Be}$  reactions are proposed as very simple and suitable systems for monitoring purposes.

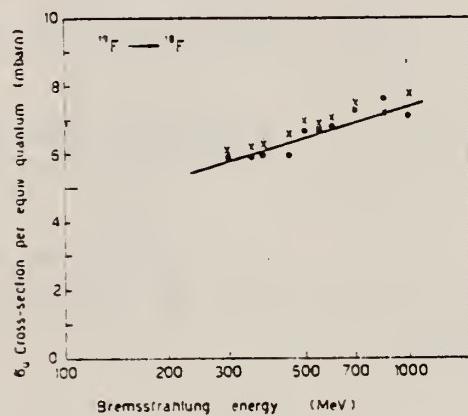


Fig. 1.  $^{19}\text{F} \rightarrow ^{18}\text{F}$  reaction cross sections per e.q. The circles represent values obtained by the Wilson quantameter; the straight line is a least-squares fit of these values. The crosses represent  $\sigma_q$  values obtained by the  $^{27}\text{Al} \rightarrow ^{24}\text{Na}$  monitor.

TABLE 2

Energy (MeV)	$\sigma_q$ (mb)			
	$^{19}\text{F} \rightarrow ^{18}\text{F}$	$^{27}\text{Al} \rightarrow ^{24}\text{Na}$	$^{197}\text{Au} \rightarrow ^{196}\text{Au}^*$	$^{12}\text{C} \rightarrow ^{7}\text{Be}^*$
260			$270 \pm 14$	
300	$5.90 \pm 0.20$	$0.37 \pm 0.01$	$258 \pm 13$	$0.37 \pm 0.01$
320		$0.39 \pm 0.01$		
350	$5.90 \pm 0.20$	$0.39 \pm 0.01$		$0.38 \pm 0.01$
380	$5.95 \pm 0.20$	$0.41 \pm 0.01$		
400			$0.42 \pm 0.01$	
420		$0.45 \pm 0.01$		
450	$5.95 \pm 0.20$	$0.48 \pm 0.01$	$249 \pm 12$	$0.44 \pm 0.02$
500	$6.65 \pm 0.20$	$0.49 \pm 0.01$		
550	$6.65 \pm 0.20$	$0.50 \pm 0.02$		$0.47 \pm 0.02$
600	$6.80 \pm 0.20$	$0.52 \pm 0.02$		
650		$0.52 \pm 0.02$	$266 \pm 13$	$0.47 \pm 0.02$
700	$7.20 \pm 0.30$	$0.56 \pm 0.02$		
750		$0.55 \pm 0.02$		
850	$7.60 \pm 0.30$	$0.60 \pm 0.02$	$246 \pm 12$	$0.49 \pm 0.03$
900		$0.59 \pm 0.02$		
1000	$7.10 \pm 0.30$	$0.66 \pm 0.02$	$249 \pm 12$	$0.51 \pm 0.03$

\* The values given in the last two columns are, in most cases, an average of two or more measurements (see figs. 3 and 4).

METHOD					REF. NO.	
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE RANGE	TYPE RANGE		
G,N	ABY	10-800	C 100-800	ACT-I	4PI	

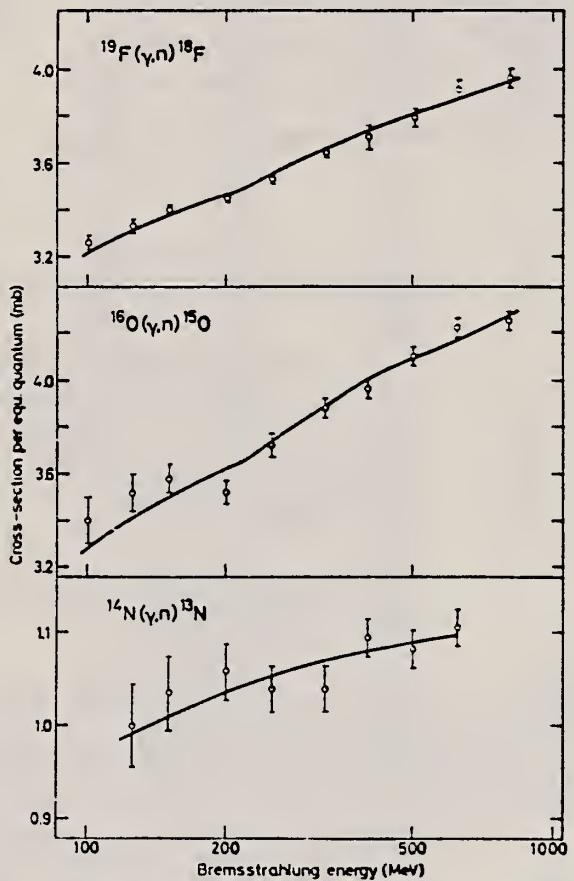


Fig. 1. Absolute yields for the  $(\gamma, \text{n})$  reactions in  $^{14}\text{N}$ ,  $^{16}\text{O}$  and  $^{19}\text{F}$ . The solid lines are the least-squares fits of the yields from low-energy processes and photomeson yield.

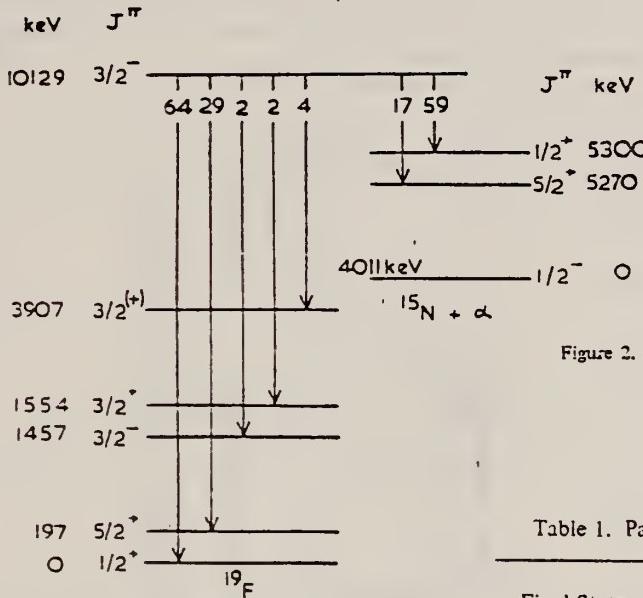
METHOD

REF. NO.

71 Wo 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P, G	ABI	10	D	2	SCD-D		DST

10=10.129 MEVFigure 2. Relative intensities of the  $\gamma$ -rays observed from the 2260 keV resonance in  $^{18}\text{O} + \text{p}$ .Table 1. Partial and Reduced Widths for the 2260 keV Resonance in  $^{18}\text{O} + \text{p}$ .

Final State ( $E_x$ , keV)	$J^\pi$	$\frac{\Gamma_p \Gamma_\gamma}{\Gamma}$ or $\frac{\Gamma_p \Gamma_{\alpha'}}{\Gamma}$ (eV)	$\Gamma_\gamma, \Gamma_\alpha$ or $\Gamma_p$ (eV)	$ M ^2$ (W.u.)	$\theta_\alpha^2$ or $\theta_p^2$ (MeV)
$^{19}\text{F}$ (g.s.)	$1/2^+$	2.4	76	0.15 (E1)	see Note 1.
$^{19}\text{F}$ (110)	$1/2^-$	<0.07	<2	<0.1 (M1)	see Note 1.
$^{19}\text{F}$ (197)	$5/2^+$	1.1	35	0.08 (E1)	
$^{19}\text{F}$ (1345)	$5/2^-$	<0.03	<1	<0.07 (M1)	
$^{19}\text{F}$ (1457)	$3/2^-$	0.06	1.9	0.14 (M1)	
$^{19}\text{F}$ (1554)	$3/2^+$	0.06	1.9	$6.3 \times 10^{-3}$ (E1)	
$^{19}\text{F}$ (3907)	$3/2^{(+)}$	0.14	4.4	0.04 (E1)	
$^{15}\text{N}$ (g.s.)	$1/2^-$	-	$7 \pm 2$ keV		0.021
$^{15}\text{N}$ (5270)	$5/2^+$	0.65	20		(0.5)
$^{15}\text{N}$ (5300)	$1/2^+$	2.3	71		(2.6)
$^{18}\text{O}$ (g.s.)	$0^+$	-	220		$7 \times 10^{-4}$

NOTE: 1. Using  $\Gamma_p/\Gamma = 0.032$  (see text). The errors in these widths are mainly due to the uncertainty in  $\Gamma_p/\Gamma$ , which is estimated to be  $\pm 50\%$ .

2. The penetrabilities were calculated using an "effective radius" =  $1.6(A_1^{1/3} + A_2^{1/3})$  fm (see text). The corresponding Wigner limit for  $\alpha$ -particle emission is 2.9 MeV.

METHOD

REF. NO.

72 Mo 6

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
He, G	RLX	19- 22	D	4- 7	NAI-D		DST

HE = HE3

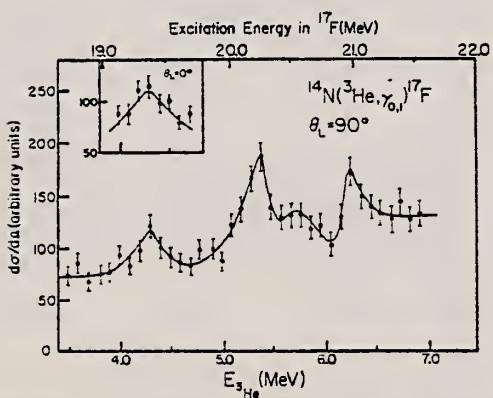


Fig. 5. Excitation functions for  $\tau$ -capture  $\gamma$ -rays from a  $^{14}\text{N}$  gaseous target. The data consist of the sum of  $\gamma_0$  and  $\gamma_1$  radiations to the ground and first excited states in  $^{17}\text{F}$ . The indicated error bars are statistical errors. The solid curves were drawn through most of the data points for aiding the eye. The bombarding energies have been corrected for energy losses in the entrance foil and target gas, and correspond to incident energies at the center of the gas cell. The curve on the upper-left part is the excitation function measured at  $\theta_L = 0^\circ$  over the resonance at 4.3 MeV.

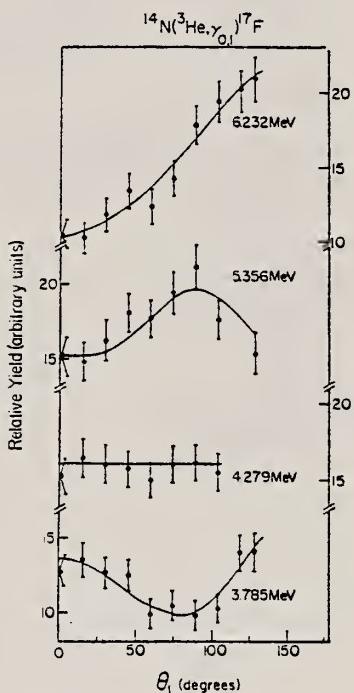


Fig. 6. Angular distributions for  $\tau$ -capture  $\gamma$ -rays from a  $^{14}\text{N}_2$  gaseous target. The bombarding energy attached on each angular distribution has been corrected for the energy loss through the entrance foil and target gas, and corresponds to the energy at the center of the gas cell. Statistical errors are indicated.

## METHOD

REF. NO.

72 Ro 3

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
A,G	LFT	5-7	D	1-3	SCD-D		DST
		(5.3-6.2)		(1.6-2.7)			

J-PI ,4 LEVELS

TABLE 5. Transition strengths from states studied

$E_i$	$J_i$	$E_f$	$J_f$	Branching ratio	$ M ^2$ (W.u.)			
					M1	E1	E2	M2
5336	$1/2^{\pm 1}$	0	$1/2^+$	$37 \pm 4$	$0.18 \pm 0.03$	$(10 \pm 1.5) \times 10^{-3}$	<2	<230
		110	$1/2^-$	$42 \pm 4$				
		197	$5/2^+$	<1				
		1346	$5/2^-$	<1.5		$(12 \pm 2) \times 10^{-3} \dagger$		
		1459	$3/2^-$	$20 \pm 2$				
		1554	$3/2^+$	<2	$<0.03$			
5618	$3/2^-$	0	$1/2^+$	<5		$<1.5 \times 10^{-4}$		<230
		110	$1/2^-$	<2	$<0.001$			
		197	$5/2^+$	$39 \pm 4$				
		1346	$5/2^-$	$61 \pm 4$	$0.068 \pm 0.018 \dagger$	$(9 \pm 2) \times 10^{-4} \dagger$		
		1459	$3/2^-$	<25	$<0.025$			
		1554	$3/2^+$	<25				
5938	$1/2^+$	0	$1/2^+$	$7 \pm 4$	$(8.4 \pm 4) \times 10^{-3}$	$(1.1 \pm 0.5) \times 10^{-3}$	$0.7 \pm 0.4$	
		110	$1/2^-$	$20 \pm 6$				
		197	$5/2^+$	$2 \pm 1$				
		1459	$3/2^-$	$63 \pm 6$		$(7.8 \pm 2.6) \times 10^{-3} \dagger$		
		1554	$3/2^+$	<2	$<0.006$			
		3907	$3/2^+$	$8 \pm 3$	$0.24 \pm 0.10 \dagger$			
6070	$7/2^+$	197	$5/2^+$	$54 \pm 5$	$0.077 \pm 0.018$	$(25 \pm 6) \times 10^{-4}$	$1.1^{+0.9}_{-0.7}$	<2
		1346	$5/2^-$	$19 \pm 2$				
		1554	$3/2^+$	$1^{+1}_{-0.5}$				
		2780	$9/2^+$	$23 \pm 3$	$0.21 \pm 0.05$	$<3 \times 10^{-3}$	$1.3^{+1.9}_{-0.7}$	<3
		3999	$7/2^-$	<2				
		4032	$9/2^-$	<1				
6088	$3/2^-$	4378	$7/2^+$	$4 \pm 1$	$0.27 \pm 0.08 \dagger$		—	<1.2
		0	$1/2^+$	$25 \pm 4$				
		110	$1/2^-$	$61 \pm 5$	$0.31 \pm 0.06$			
		197	$5/2^+$	$14 \pm 3$		$(32 \pm 7) \times 10^{-4}$	$0.15^{+0.28}_{-0.12}$	<2.7
		1346	$5/2^-$	<0.5	$<0.005$			
		1459	$3/2^-$	<1.5	$<0.015$			
6160	$7/2^-$	1554	$3/2^+$	<1		$<5 \times 10^{-4}$	$0.47^{+1.1}_{-0.40}$	
		197	$5/2^+$	$31 \pm 3$				
		1346	$5/2^-$	$65 \pm 4$	$0.16 \pm 0.04$			
		1459	$3/2^+$	$1.3 \pm 0.6$	—	$0.34^{+0.15}_{-0.12}$	$0.12 \pm 0.06$	
		2780	$9/2^+$	<1				
		3999	$7/2^-$	$1.6 \pm 0.6$	$(5 \pm 3) \times 10^{-3} \dagger$			
		4032	$9/2^-$	$2.3 \pm 0.3$	$(7 \pm 3) \times 10^{-3} \dagger$			
		4378	$7/2^+$	<1				
		4681	$5/2^-$	<2	$<0.02$			

\*Assumed pure M1 although there is indication of a possible large E2 component.

†Assumed pure M1 or E1.

METHOD

REF. NO.

72 Sh 2

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, PG	SPC	0-14	C	14	SCD-D		87
G, AG	SPC	0-14	C	14	SCD-D		87
G, G/	SPC	0-14	C	14	SCD-D		87

TABLE I  
Gamma-rays resulting from the photon bombardment of a  $(CF_2)_n$  (teflon) target

$E_\gamma$ (MeV)	Observed peak	Relative intensity	Assignment	
			reaction	transition
1.66	F	38 $\pm$ 11	$^{19}F(\gamma, p\gamma)^{18}O$	$3.64 \rightarrow 1.98^a)$
1.94	F	20 $\pm$ 10	$^{19}F(\gamma, p\gamma)^{18}O$	$3.92 \rightarrow 1.98^a)$
1.98	F	158 $\pm$ 10	$^{19}F(\gamma, p\gamma)^{18}O$	$1.98 \rightarrow 0^a)$
3.91	D, F	17 $\pm$ 8	$^{19}F(\gamma, \gamma')^{19}F$	$3.91 \rightarrow 0$
5.27	D, S, F	71 $\pm$ 2	$^{19}F(\gamma, z\gamma)^{15}N$	$5.27 \rightarrow 0$
5.30	D, S, F	93 $\pm$ 4	$^{19}F(\gamma, z\gamma)^{15}N$	$5.30 \rightarrow 0$
6.11	D, S, F	13.9 $\pm$ 1.3	$^{19}F(\gamma, \gamma')^{19}F$	$7.66 \rightarrow 1.56$
7.66	D, S, F	11.5 $\pm$ 0.8	$^{19}F(\gamma, \gamma')^{19}F$	$7.66 \rightarrow 0$

<sup>a)</sup> The transition is identified by comparing the transition energy with that from the level scheme for  $^{18}O$  given in ref. <sup>50</sup>.

TABLE 5  
Excitation energies and ground state transition widths obtained from the  $^{19}F(\gamma, \gamma')^{19}F$  reaction

Excitation energy (keV)		$J^\pi; T$	$\Gamma_{\gamma 0}/\Gamma_\gamma$	$(2J+1)\Gamma_{\gamma 0}$ (eV <sup>-1</sup> )
present work	previous work			
3906 $\pm$ 6	3905 <sup>a)</sup>	$\frac{1}{2}^{++}$ <sup>b)</sup>	$0.44 \pm 0.10^b)$	$0.04 \pm 0.03$
7663 $\pm$ 4	7660 $\pm$ 3 <sup>c)</sup>	$\frac{1}{2}^+; T = \frac{1}{2}^+$ <sup>c)</sup>	$0.49 \pm 0.04^b)$	$2.6 \pm 0.4$

<sup>a)</sup> The error for  $(2J+1)\Gamma_{\gamma 0}$  only includes the statistical error. An estimate of the uncertainty associated with the shape of the incident bremsstrahlung is not included. The ground state width of the 7663 keV level is normalized to the value obtained by Aitken et al. <sup>10</sup> from the  $^{15}N(z, \gamma)^{19}F$  reaction:  $\Gamma_{\gamma 0} = 0.65 \pm 0.11$  eV. The value of  $\Gamma_\gamma \Gamma_z/\Gamma = 1.5 \pm 0.3$  eV [ref. <sup>10</sup>] is used to estimate the ground state branching  $\Gamma_{\gamma 0}/\Gamma$ .

<sup>b)</sup> Refs. <sup>11, 12</sup>.

<sup>c)</sup> Ref. <sup>10</sup>.

<sup>d)</sup> This value is calculated from the observed relative intensity at the scattering angle of 87° on the assumption that the transitions to the lower states are of pure dipole character.

<sup>10</sup> J.H. Aitken et al. Phys. Lett. **30B** (1969) 473.

<sup>11</sup> H.G. Benson et al. Nucl. Phys. **A126** (1969) 305.

<sup>12</sup> K.W. Allen et al., quoted in ref. 11.

<sup>50</sup> A.E. Litherland et al. Nucl. Phys. **44** (1963) 220.

ELEM. SYM.	A	Z
F	19	9

METHOD					REF. NO.	72 Th 5	hmg
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,PG	ABI	8- 25	C	19- 25	SCD-D		DST
G,NG	ABI	10- 25	C	19- 25	SCD-D		DST
G,AG	ABI	4- 25	C	19- 25	SCD-D		DST

GAMMA DST

TABLE 2. Yields of gamma rays from the reaction  $^{19}\text{F}(\gamma, \gamma')$

Residual nucleus	State (MeV)	$J^\pi$	Known $\gamma$ decay	Relative yield						Estimate of $\int_{25}^{25} \frac{d\sigma(150)}{d\Omega} dE$ (MeV mb/sr)	
				$E_0 = 19 \text{ MeV}$		$E_0 = 21.5 \text{ MeV}$		$E_0 = 25 \text{ MeV}$			
				$\theta = 90^\circ$	$\theta = 150^\circ$	$\theta = 90^\circ$	$\theta = 150^\circ$	$\theta = 90^\circ$	$\theta = 150^\circ$		
$^{18}\text{F}$	0.940	$3^+$	GS	0.70	0.60	0.90	0.90	1.0	1.0	$1.25 \pm 0.3$	
	1.040	$0^+$	GS			0.25	0.20	0.35	0.35	$0.45 \pm 0.11$	
$^{18}\text{O}$	1.977	$2^+$	GS	0.28	0.65	0.85	1.10	0.90	1.40	$1.75 \pm 0.4$	
	3.630	$0^+$	1.977	0.20	0.25	0.25	0.45	0.50	0.70	$0.9 \pm 0.2$	
$^{15}\text{N}$	5.27	$5/2^+$	GS	0.07	0.09	0.45	0.35	0.55	0.60	$0.75 \pm 0.2$	



METHOD					REF. NO.	
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE	RANGE	TYPE	RANGE
G,XN	ABX	10-19	C	10-19	BF3-I	4PI

665

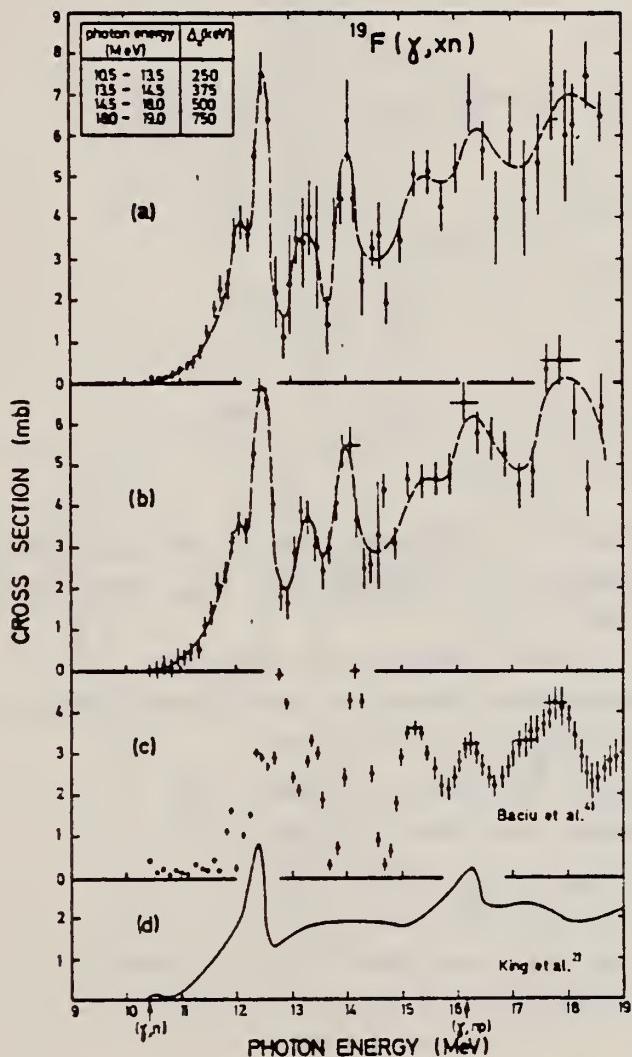


Fig. 3. Total photoneutron cross section  $\sigma[(\gamma, n) + (\gamma, np)]$  for  $^{19}\text{F}$ : (a) shows our results using the VBPL unfolding procedure, while (b) gives the results from a Cook analysis of the same data (the broken lines serve merely to guide the eye); (c) and (d) represent the other existing photoneutron cross-section data.

(OVER)

TABLE I  
Photonuclear resonance energies observed in  $^{19}\text{F}$

	(γ, p)		(e, e'p)		(γ, T)		(γ, n)		this work	
	ref. <sup>2)</sup>	ref. <sup>3)</sup>	ref. <sup>10)</sup>	ref. <sup>11)</sup>	ref. <sup>9)</sup>	ref. <sup>12)</sup>	ref. <sup>13)</sup>	ref. <sup>2)</sup>	ref. <sup>3)</sup>	
10.4		10.0			(10.1)					
		10.96			(10.9)		(10.6)	11.0		
11.4			11.42	11.4				11.56	(11.40) (11.59) (11.72) (11.82)	
11.9	11.8	12.0		11.9		(11.8)		11.90	(11.90) 12.10 12.38 12.5	
					12.5	12.4	12.5	12.42	(12.65) (12.84) (13.04)	
(12.8)	12.55	(12.6)		12.74				12.88	(13.29) 13.82	13.3
13.6					14.0	13.7	14.0	14.0	14.08	14.0
	14.19	(14.45)				14.6		15.5	15.23	15.4
15.4	15.41	15.5	15.8	15.7						
16.5	16.61		16.7	16.8	16.0	16.1		16.20	16.24	16.3
					17.3	17.2	17.0	(17.12) 17.91 (19.06)		18.0
(18.1)			(18.8)	18.7	18.7					
			(19.8)		19.5	19.3				

- <sup>2</sup> J. D. King, R. N. H. Haslam & W. J. McDonald, Can. J. Phys. 38 (1960) 1069.  
<sup>3</sup> G. Baciu, D. Catana, C. Deberth & I. Raileanu, Rev. Roum. Phys. 12 (1967) 385;  
G. Baciu, St. Cerc. Fiz. 23 (1971) 773.  
<sup>4</sup> G. Baciu et al. Inst. for Atomic Physics report M-43-1969.  
<sup>5</sup> N. K. Sherman et al., National Res. Council of Canada report NRC-12180 (1972).  
<sup>7</sup> B. Forkman & I. Wahlstrom, Ark. Fys. 18 (1960) 339.  
<sup>8</sup> W. R. Dodge and W. G. Barber, Phys. Rev. 127 (1962) 1746.  
<sup>9</sup> K. M. Murray and W. L. Bendel, Phys. Rev. 132 (1963) 1134.  
<sup>10</sup> S. Seki et al., J. Phys. Soc. Jap. 19 (1964) 1999.  
<sup>11</sup> K. Abe et al., J. Phys. Soc. Jap. 25 (1968) 1507.  
<sup>12</sup> B. S. Dolbilkin et al., Izv. Akad. Nauk SSSR (fiz.) 30 (1966) 349.  
<sup>13</sup> N. Bezic et al., Nucl. Phys. A128 (1969) 426.

METHOD	REF. NO.				
			72 Va 3		hvm
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
G,XN	ABX	10- 19	C	10- 19	BF3-I
					4PI

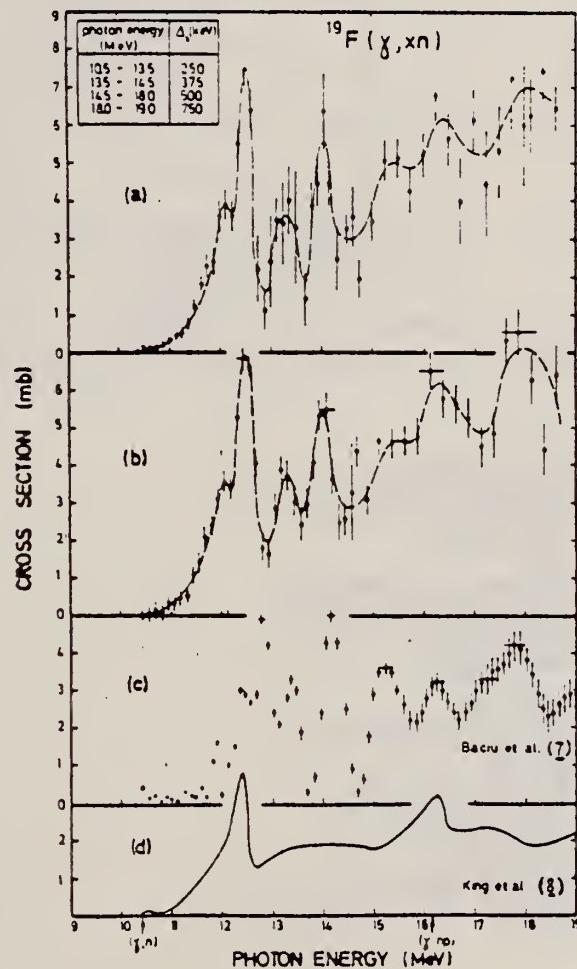


Fig. 1. Total photoneutron cross section for  $^{19}\text{F}$ . Our results following (a) the VBPL method and (b) the Cook analysis. Previous data (c) by Baciu et al. (7) and (d) by King et al. (8)

(over)

Table 1. Photonicuclear resonance energies observed in  $^{19}\text{F}$ 

(γ,p)				(e,e'p)	(γ,T)		(γ,n)					
Forkman (13)	Murray (14)	Seki (15)	Abe (16)	Dodge (17)	Dolbilkin (9)	Bezic (10)	King (8)	Baciu (7)	Baciu (18)	Sherman (11)	This work	
10.4		10.0			(10.1)							
11.4		10.96			11.42	11.4	(10.9)	(10.6)	11.0			
11.9	11.8	12.0		11.9			(11.8)			11.56	(11.40) (11.59) (11.72) (11.82) (11.90)	
(12.8)	12.55	12.85	(12.6)	12.74			12.5	12.4	12.1	11.90	12.10 12.38 (12.65) (12.84) (13.04) (13.29)	12.1 12.5
13.6	14.19	(14.45)				14.0	13.7			12.88	13.28 13.82	13.3
15.4	15.41	15.8	15.5	15.7			14.6	14.0	14.0	14.08		14.0 15.4
16.5	16.61		16.7		16.8		16.0	16.1		16.20	16.24	16.3
(18.1)			(18.8) (19.8)	18.7	19.5		17.3	17.2	17.0	(17.12) 17.91 (19.06)		18.0

## References

- (1) R.A. Alvarez et al., Phys. Rev. C4 (1971) 1673
- (2) J.S. Pruitt and S.R. Domen, NBS Monograph 48 (1962)
- (3) E. Bramanis et al., Nucl. Instr. and Meth. 100 (1972) 59
- (4) B.C. Cook, Nucl. Instr. and Meth. 24 (1963) 256
- (5) L.I. Schiff, Phys. Rev. 83 (1951) 252
- (6) B. Cook and C. Jones, Nucl. Instr. and Meth. 59 (1968) 229
- (7) G. Baciu et al., Institute for Atomic Physics Rep. M-43-1969
- (8) J.D. King et al., Can. J. Phys. 38 (1960) 1069
- (9) B.S. Dolbilkin et al., Izv. Akad. Nauk. SSSR (ser. fiz.) 30 (1966) 349
- (10) N. Bezic et al., Nucl. Phys. A128 (1969) 426
- (11) N. Sherman et al., Nat. Res. Council of Can. NRC-12180 (1972)
- (12) S. Fujii, Prog. Theor. Phys. 21 (1959) 511
- (13) B. Forkman and I. Wahlström, Ark. Fys. 18 (1960) 339
- (14) K.M. Murray and W.L. Bendel, Phys. Rev. 132 (1963) 1134
- (15) S. Seki et al., J. Phys. Soc. Jap. 19 (1964) 1999
- (16) K. Abe et al., J. Phys. Soc. Jap. 25 (1968) 1507
- (17) W.R. Dodge and W.C. Barber, Phys. Rev. 127 (1962) 1746
- (18) G. Baciu et al., Rev. Roum. Phys. 12 (1967) 385; G. Baciu St. Cerc. Fiz. 23 (1971) 773.

ELEM. SYM.	A	Z
F	19	9
METHOD	REF. NO.	
	73 Be 10	hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE	RANGE	
G, N	ABX	11- 29	D	11- 29	BF3-I
G, 2N	ABX	22- 29	D	22- 29	BF3-I

217+

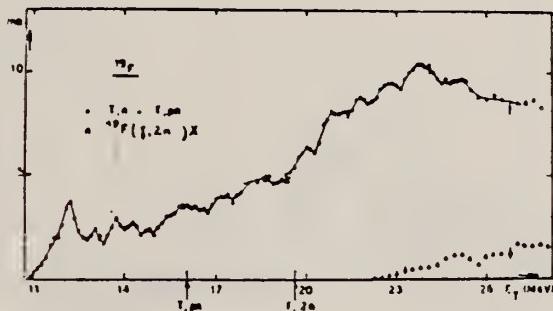


Fig. 10 Partial  $\sigma(\gamma, n) + \sigma(\gamma, pn)$  and  $\sigma(\gamma, 2n \dots)$  of  $^{19}\text{F}$ .

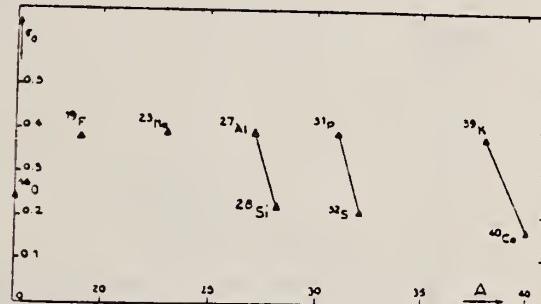


Fig. 13 Integrated photoneutron cross-sections for s-d shell nuclei.

ELEM. SYM.	A	Z
F	19	9

METHOD

REF. NO.
73 Ga 5

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XN	ABX	10- 25	G	10- 25	BF3-I		4PI

726

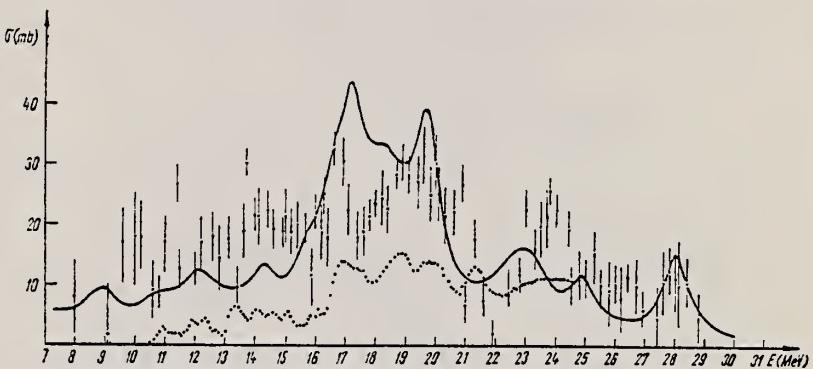


Fig. 6. Theoretical  $E1$  photoabsorption cross section for  $^{19}\text{F}$  (full line). Experimental photoabsorption cross section reported by Dolbilkin [10] (points with errors). Cross section of  $^{19}\text{F}(\gamma, xn)$  reaction (point line)

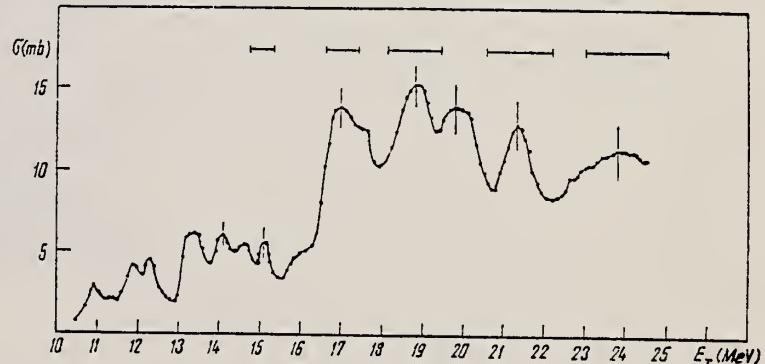
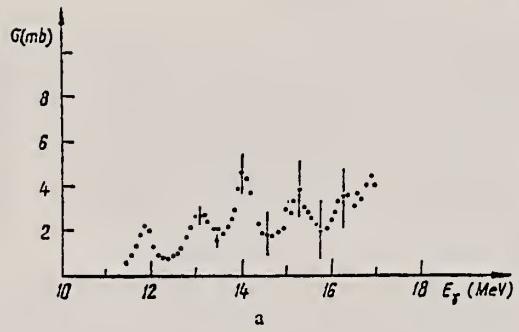


Fig. 4. Least structure solution for  $^{19}\text{F}(\gamma, xn)$  cross section. The statistical errors and the resolution function are shown at representative energies

Fig. 3a and b. Penfold and Leiss solution for  $^{19}\text{F}(\gamma, xn)$  cross section. a Schiff bremsstrahlung spectrum, b FDTTB spectrum

ELEM. SYM.	A	Z
F	19	9
REF. NO.	73 Di 4	hmg

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, SPL	ABY	THR-999	C	999	ACT-I		4PI

999 = 1 GEV

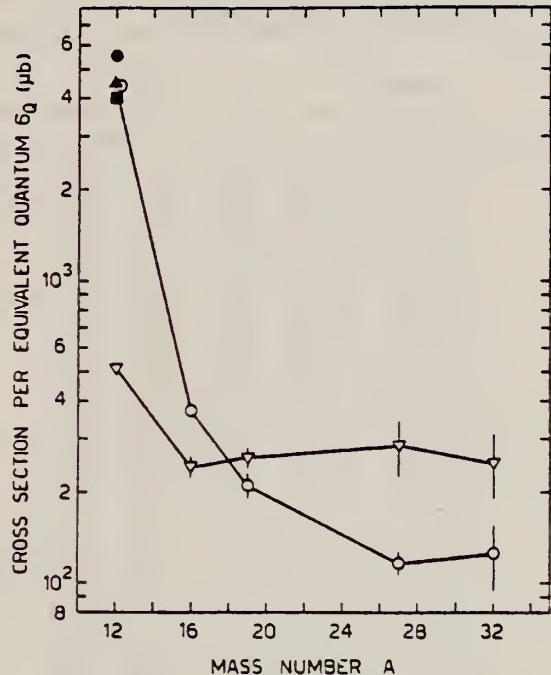


FIG. 3. Yields of  $^{11}\text{C}$  and  $^7\text{Be}$  versus the mass number of the target nucleus. Filled circle:  $^{11}\text{C}$ , Ref. 16. Filled triangle:  $^{11}\text{C}$ , Ref. 17. Filled square:  $^{11}\text{C}$ , Ref. 8. Open circles:  $^{11}\text{C}$ , present work. Reversed open triangles:  $^7\text{Be}$ , present work.

<sup>8</sup> G. Andersson et al., Nucl. Phys. A197, 44 (1972).

<sup>16</sup> V. di Napoli et al., Nuovo Cimento 55B, 95 (1968).

<sup>17</sup> A. Masaike, J. Phys. Soc. Japan 19, 427 (1964).



METHOD

REF. NO.

Page 1 of 3

73 Ha 1

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	FMF	0- 2	D	61-121	MAG-D		DST

TABLE II. Elastic and inelastic electron scattering form factors for  $^{19}\text{F}$ .

3 LEVELS .2-1.6 ME

Level	$\theta$ (deg) <sup>a</sup>	E (MeV) <sup>b</sup>	q (fm $^{-1}$ )	F <sup>2</sup> (q)		Level	$\theta$ (deg) <sup>a</sup>	E (MeV) <sup>b</sup>	q (fm $^{-1}$ )	F <sup>2</sup> (q)	
				Value	standard deviation <sup>c</sup>					Value	standard deviation <sup>c</sup>
$\frac{1}{2}^+$ (g.s.)	110.75	66.02	0.550	0.4352	0.00100	$\frac{1}{2}^-$ (1.346 MeV)	110.75	66.02	0.543	$1.19 \times 10^{-4}$	$0.52 \times 10^{-4}$
	110.75	71.02	0.592	0.3463	0.00110		110.64	71.02	0.585	$1.84 \times 10^{-4}$	$0.45 \times 10^{-4}$
	110.64	71.03	0.591	0.3721	0.00094		110.40	86.05	0.709	$3.97 \times 10^{-4}$	$0.83 \times 10^{-4}$
	110.64	86.05	0.716	0.21904	0.00053		110.64	101.21	0.833	$6.54 \times 10^{-4}$	$0.86 \times 10^{-4}$
	110.40	101.21	0.841	0.11834	0.00102		110.64	121.00	0.998	$10.58 \times 10^{-4}$	$0.60 \times 10^{-4}$
	110.64	101.17	0.842	0.11790	0.00091		145.82	60.88	0.580	$2.14 \times 10^{-4}$	$0.80 \times 10^{-4}$
	110.64	121.00	1.006	0.04509	0.00080		145.82	73.94	0.705	$3.91 \times 10^{-4}$	$1.10 \times 10^{-4}$
	145.82	60.88	0.589	0.3993	0.00105		145.40	87.96	0.840	$6.85 \times 10^{-4}$	$0.72 \times 10^{-4}$
	145.79	68.55	0.663	0.2875	0.00170		145.79	104.59	1.001	$9.80 \times 10^{-4}$	$0.62 \times 10^{-4}$
	145.82	73.94	0.715	0.2297	0.00117		163.21	85.41	0.846	$6.30 \times 10^{-4}$	$1.92 \times 10^{-4}$
	145.70	74.45	0.720	0.2201	0.00132		$\frac{1}{2}^+$ (1.554 MeV)	110.75	66.02	$1.34 \times 10^{-3}$	$0.12 \times 10^{-3}$
	145.40	87.96	0.849	0.11278	0.00089		110.64	71.02	0.584	$1.52 \times 10^{-3}$	$0.14 \times 10^{-3}$
	145.79	104.59	1.011	0.04140	0.000119		110.64	86.05	0.708	$2.57 \times 10^{-3}$	$0.11 \times 10^{-3}$
	145.70	104.65	1.011	0.04095	0.000102		110.40	101.21	0.832	$2.76 \times 10^{-3}$	$0.11 \times 10^{-3}$
	163.21	85.41	0.855	0.11775	0.00384		110.64	121.00	0.997	$2.36 \times 10^{-3}$	$0.07 \times 10^{-3}$
	$\frac{3}{2}^+$ (0.197 MeV)	110.64	86.05	0.712	$3.20 \times 10^{-3}$	$0.44 \times 10^{-3}$	145.82	60.88	0.579	$1.75 \times 10^{-3}$	$0.20 \times 10^{-3}$
		110.40	101.21	0.938	$3.52 \times 10^{-3}$	$0.37 \times 10^{-3}$	145.82	73.94	0.704	$2.33 \times 10^{-3}$	$0.27 \times 10^{-3}$
		110.64	121.00	1.003	$3.52 \times 10^{-3}$	$0.34 \times 10^{-3}$	145.50	87.96	0.839	$2.55 \times 10^{-3}$	$0.10 \times 10^{-3}$
		145.82	73.94	0.711	$3.52 \times 10^{-3}$	$0.93 \times 10^{-3}$	145.79	104.59	1.000	$2.42 \times 10^{-3}$	$0.08 \times 10^{-3}$
		145.70	74.45	0.717	$3.18 \times 10^{-3}$	$1.02 \times 10^{-3}$	163.21	85.41	0.844	$3.41 \times 10^{-3}$	$0.26 \times 10^{-3}$
		145.40	87.96	0.946	$3.98 \times 10^{-3}$	$0.37 \times 10^{-3}$					
		145.79	104.59	1.006	$4.01 \times 10^{-3}$	$0.36 \times 10^{-3}$					
		163.21	85.41	0.851	$4.28 \times 10^{-3}$	$0.78 \times 10^{-3}$					

<sup>a</sup> Laboratory angle.<sup>b</sup> Laboratory kinetic energy.<sup>c</sup> Standard deviation for statistical errors only; estimated ±2% systematic error not included.TABLE IV. Transition charge parameters for  $^{19}\text{F}$ .

Level	$B(EL, 0)† (e^2 \text{ fm}^{2L})$	$ M^2  (\text{W.u.})$	$\langle r^2_{\pi} \rangle^{1/2} (\text{fm})$	$\langle r^4_{\pi} \rangle^{1/4} (\text{fm})$
$\frac{1}{2}^+$ (0.197)	$52^{+30}_{-24}$	$5.73^{+3.30}_{-2.84}$	$3.75^{+1.08}_{-1.56}$	$3.60^{+0.73}_{-3.66}$
$\frac{1}{2}^-$ (1.346)	$608^{+221}_{-187}$	$9.45^{+3.13}_{-2.91}$	$4.30^{+0.88}_{-1.10}$	$4.13^{+0.68}_{-1.44}$
$\frac{3}{2}^+$ (1.554)	$35.5^{+3.9}_{-3.7}$	$5.89^{+0.55}_{-0.61}$	$3.44^{+0.79}_{-0.32}$	$2.99^{+0.37}_{-0.81}$

(over)

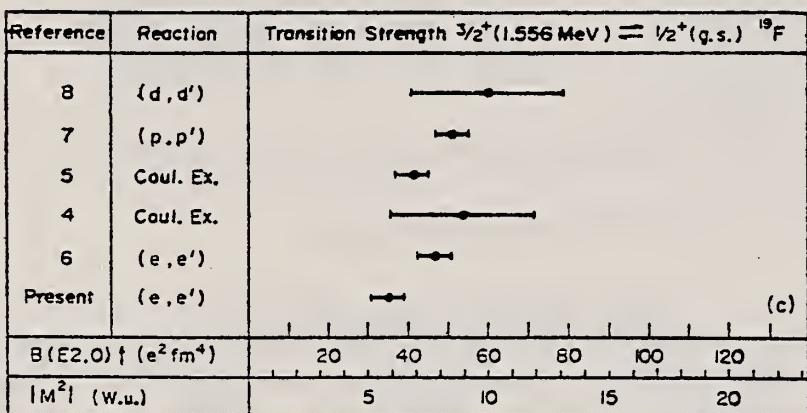
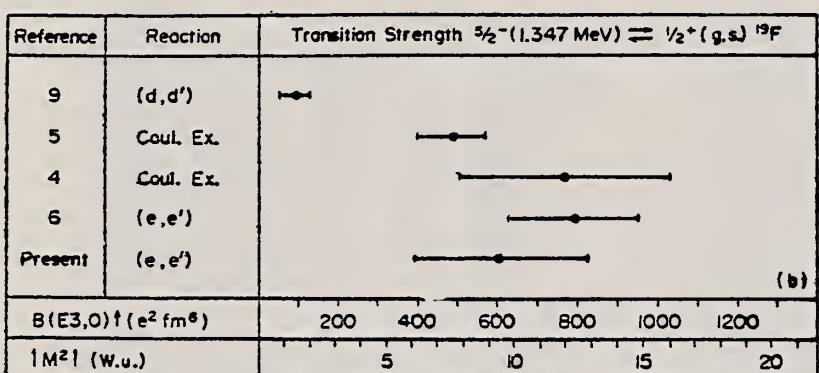
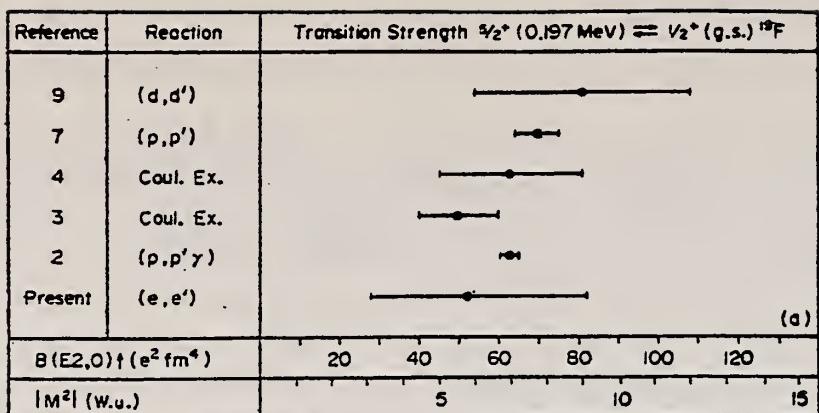


FIG. 4. Comparison of transition strengths for  ${}^{19}\text{F}$  levels derived by various workers. (a)  $\frac{1}{2}^+$  (0.197-MeV) level.  
 (b)  $\frac{5}{2}^-$  (1.347-MeV) level. (c)  $\frac{3}{2}^+$  (1.556-MeV) level.

METHOD

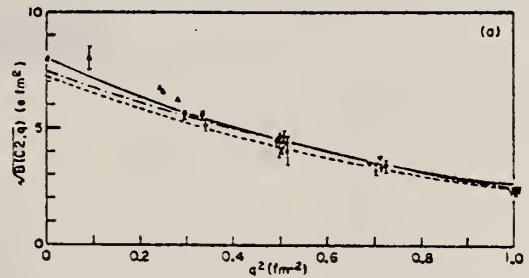
REF. NO.

Page 3 of 3

73 Ha 1

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	



<sup>2</sup>J.A. Becker, J.W. Olness, and D.H. Wilkinson.  
 Phys. Rev. 155, 1089 (1967).

<sup>6</sup>T. Walcher and P. Strehl, Z. Physik 232, 342 (1970).

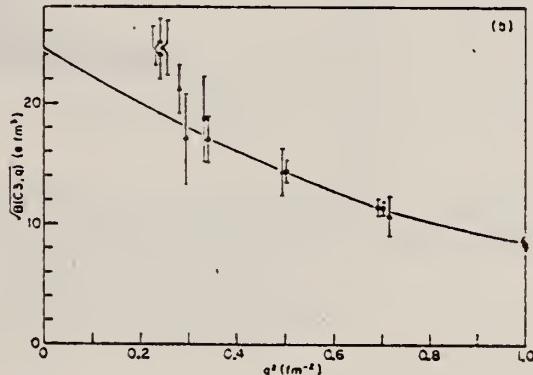


FIG. 3. Analysis of inelastic electron scattering from <sup>19</sup>F. (a)  $\frac{1}{2}^+$  (0.197-MeV) and  $\frac{3}{2}^+$  (1.554-MeV) levels. ●, present data,  $\frac{1}{2}^+$  level. ▼, present data,  $\frac{3}{2}^+$  level; ordinate scaled by  $(\frac{1}{2})^{1/2}$ . ▲, data of Ref. 6; ordinate scaled by  $(\frac{1}{2})^{1/2}$ . ■, lifetime measurement,  $\frac{1}{2}^+$  level, of Ref. 2. ----, model independent fit,  $\frac{1}{2}^+$  level; ordinate scaled by  $(\frac{1}{2})^{1/2}$ . —, rotational model fit based on the measured ground-state charge distribution and the lifetime measurement of Ref. 2. The ordinate as given applies to the  $\frac{1}{2}^+$  state. Ordinates for the  $\frac{3}{2}^+$  state are obtained by multiplying the plotted ordinates by  $(\frac{1}{2})^{1/2}$ . (b)  $\frac{1}{2}^-$  (1.346-MeV) level. ●, present data. ▲, data of Ref. 6. —, model independent fit.

ELEM. SYM.	A	Z
F	19	9

METHOD

REF. NO.

73 Mo 9

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N	RLY	10- 39	C	10- 39	ACT-I		4PI
E, N	RLY	10- 39	D	10- 39	ACT-I		4PI

YIELD/PHOTO/ELECTRO

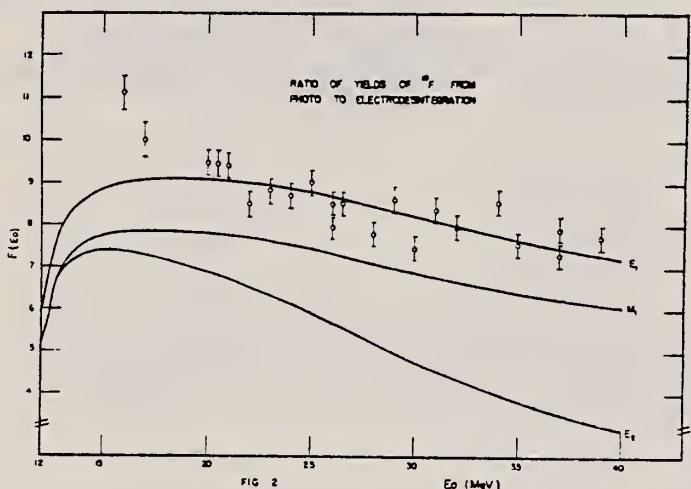


FIG. 2

ELEM. SYM.	A	Z
F	19	9

METHOD

REF. NO.

73 Sh 9

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N	ABX	11- 21	C	13- 21	TOF-D		90

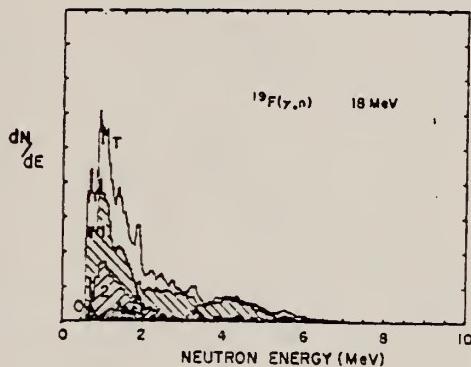
GND AND EXCIT STATE

Figure 1 - Photoneutron spectrum of  $^{19}\text{F}$  due to 18 MeV bremsstrahlung, labelled "T". The numbered curves result from folding the photon spectrum with: "0" - the ground-state cross section (stippled); "1" - the cross section to 1.04 MeV excitation in  $^{19}\text{F}$ . The remainder is "2".

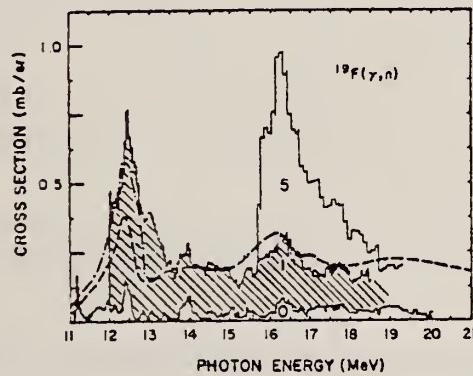


Figure 2 - The  $90^\circ$  differential cross section for  $(\gamma, n)$  processes in  $^{19}\text{F}$ . The region "0" is  $\sigma(\gamma, n_0)$ . The hatched region "1" is  $\sigma(\gamma, n_1)$ . The region "5" results from curve 2 of Fig. 1 assuming transitions to the 4.74 MeV ( $T = 1$ ) level of  $^{19}\text{F}$ . The dashed curve derives from King et al.<sup>3</sup>, assuming  $d \rightarrow f$  and  $d \rightarrow p$  transitions. The dash-dot curve assumes  $p \rightarrow d$  transitions. If region "5" is due to the  $^{19}\text{F}(\gamma, nn)$  reaction, there is no disagreement.



METHOD			REF. NO.	
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR
			TYPE RANGE	TYPE RANGE
E, T	ABX	18- 23	D UKN	MAG-D

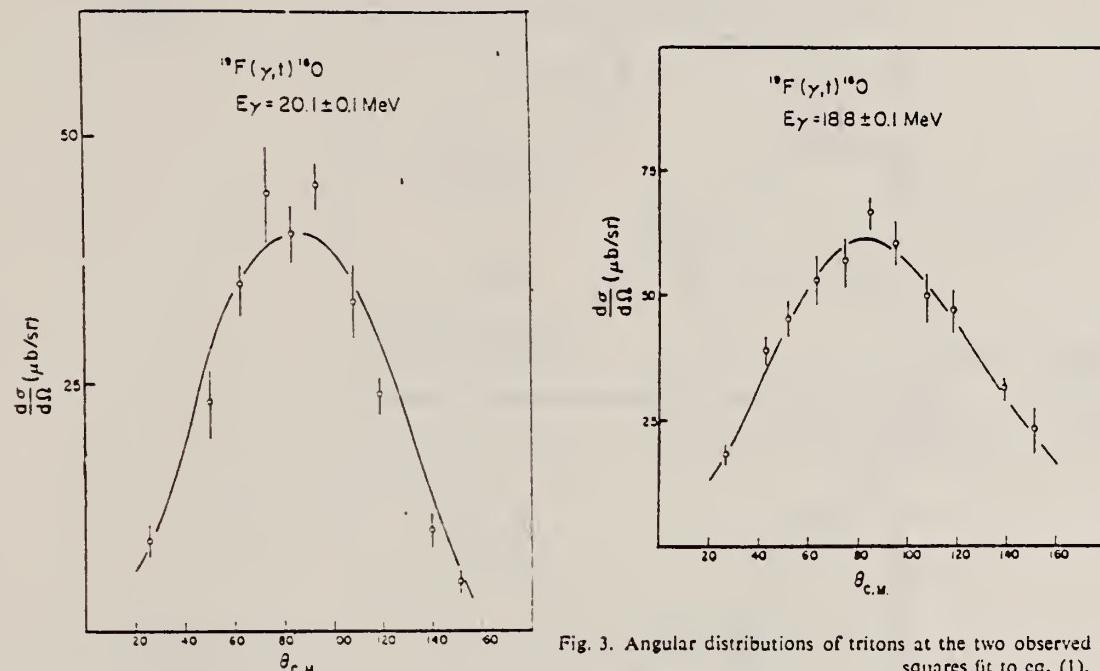
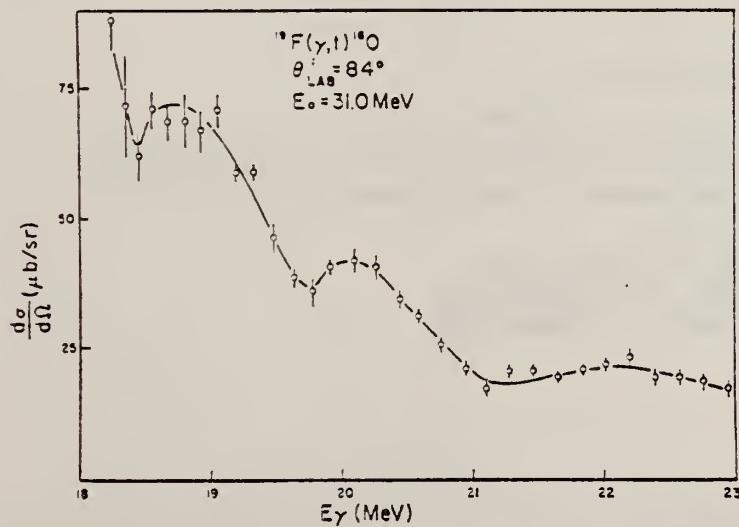
 $^{19}\text{F}(\gamma, t)$ GROUND STATE

Fig. 3. Angular distributions of tritons at the two observed resonances. The solid line is the least squares fit to eq. (1).

Fig. 4. The differential cross section at  $84^\circ$  for  $E_0 = 31$  MeV. For  $E_\gamma \leq 25$  MeV non-ground-state transitions are possible.

(over)

TABLE I  
Integrated cross sections for  $^{19}\text{F}$  in MeV · mb

Total absorption	$(\gamma, \text{xn})$	$(\gamma, t)$
$\int_{18}^{23} \sigma dE$	$\approx 170$ <sup>a)</sup>	1.2
$\int_{20.1 \text{ resonance}} \sigma dE$	3.5 <sup>b)</sup>	$\approx 2^\circ$ <sup>c)</sup>

<sup>a)</sup> Ref. <sup>2)</sup>.

<sup>b)</sup> Ref. <sup>9)</sup>.

<sup>c)</sup> Ref. <sup>1)</sup>.

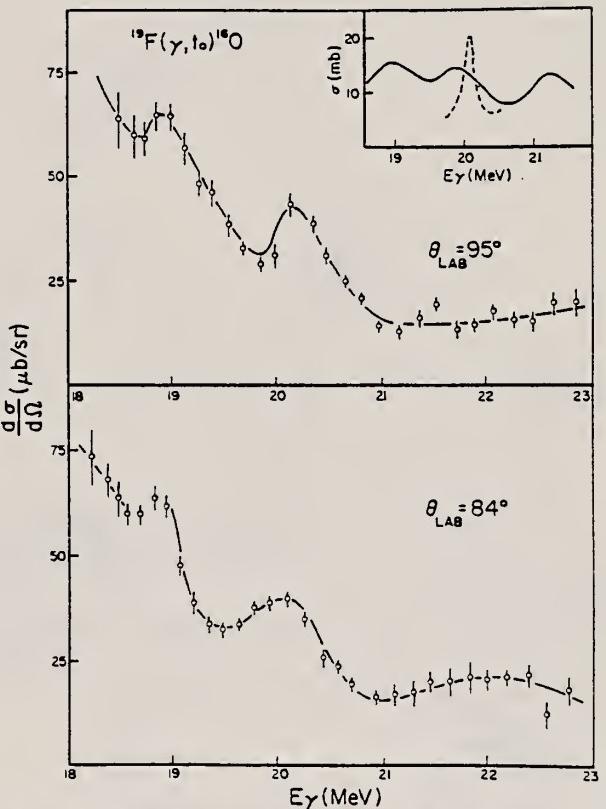


Fig. 2. The  $^{19}\text{F}(\gamma, t)^{16}\text{O}$  ground state differential cross section at  $\theta_{\text{Lab}} = 84^\circ$  and  $95^\circ$ . The solid line in the inset is taken from the  $^{19}\text{F}(\gamma, \text{xn})$  work of Catana *et al.* [ref. <sup>1)</sup>]; the dashed line is the total absorption measurement of Tessler and Stephens [ref. <sup>9)</sup>].

- 1) D. Catana *et al.*, Z. Phys. 261 (1973) 125
- 2) N. Bezic *et al.*, Nucl. Phys. A128 (1969) 426
- 9) G. Tessler *et al.*, Phys. Rev. 135 (1964) B129

A. Veyssiere, H. Beil, R. Bergere, P. Carlos, A. Lepretre, and  
A. De Miniac  
Nucl. Phys. A227, 513 (1974)

ELEM. SYM.	A	Z
F	19	9

## METHOD

REF. NO.

74 Ve 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE	RANGE		
* G,N	ABX	10- 28	D	10- 28	BF3-I	4PI
** G,ZN	ABX	20- 28	D	20- 28	BF3-I	4PI

\* 881  
\*\* 880 +

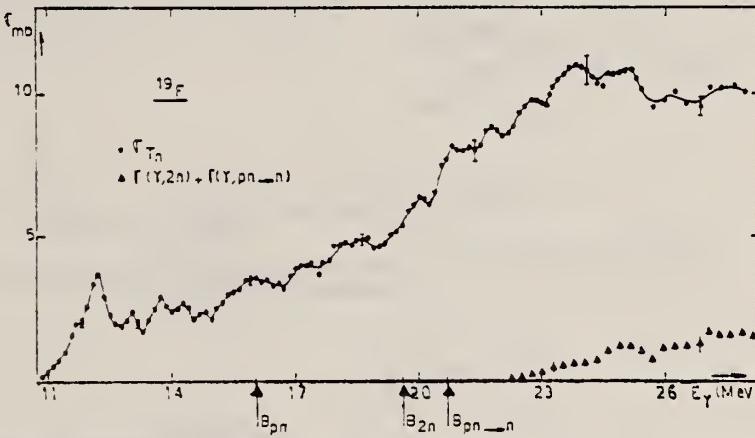


Fig. 3. Photoneutron cross sections  $\sigma_{Tn}$  and  $[\sigma(\gamma, 2n) + \sigma(\gamma, pn \rightarrow n)]$  of  $^{19}F$ .

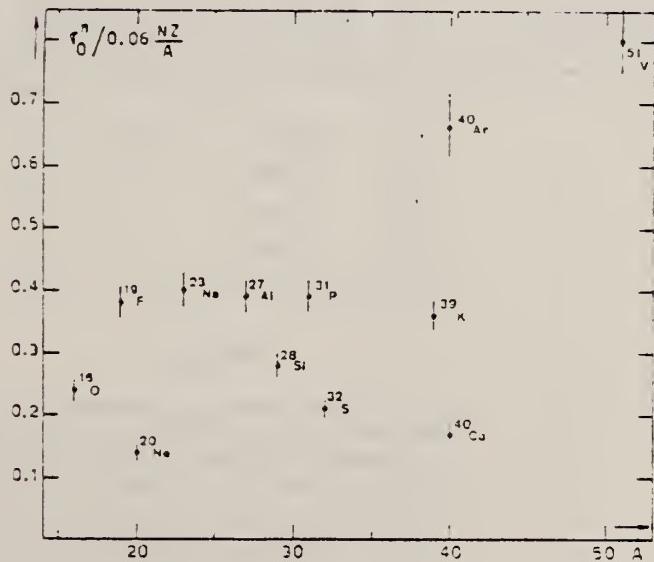


Fig. 22. Ratio of experimental integrated photoneutron cross section  $\sigma_0^n$  over the Thomas, Reich, and Kuhn sum rule  $[0.06 NZ/A]$ . Numerical values and upper integration limits  $E_{\text{nt}}$  are taken from table 3. Also  $d\sigma_0^n = \pm 7\%$  for all nuclei.

(over)

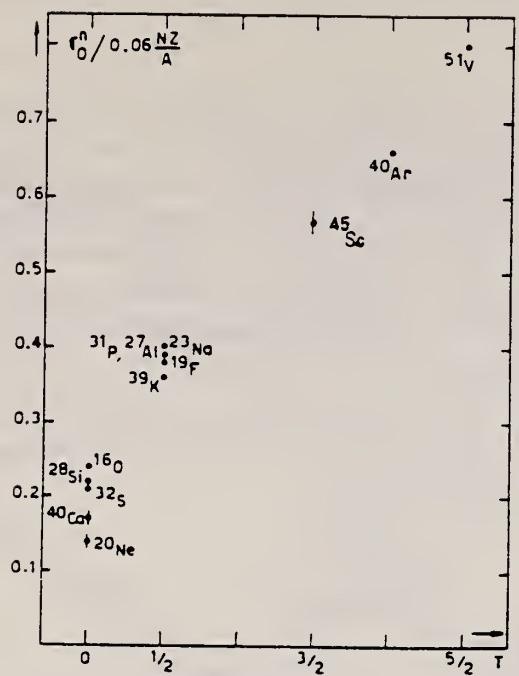


Fig. 24. The  $[\sigma_0^n / (0.06 NZ/A)]$  ratio as a function of isospin  $T$ . Possible overall errors of  $\pm 7\%$  are to be applied to all nuclei shown.

TABLE 3  
Experimental integrated photoneutron cross sections  $\sigma_0^n = \int_0^{E_M} \sigma_{Tn}(E) dE$  compared with the classical sum rule  $[0.06 NZ/A]$  of Thomas, Reich and Kuhn

Nucleus	$T = 0$					$T = \frac{1}{2}$					$T = \frac{3}{2}$	$T = 2$	$T = \frac{5}{2}$
	${}^{16}\text{O}$	${}^{20}\text{Ne}$	${}^{28}\text{Si}$	${}^{32}\text{S}$	${}^{40}\text{Ca}$	${}^{19}\text{F}$	${}^{23}\text{Na}$	${}^{27}\text{Al}$	${}^{31}\text{P}$	${}^{39}\text{K}$	${}^{45}\text{Sc}$	${}^{40}\text{Ar}$	${}^{51}\text{V}$
$\sigma_0^n$ (MeV · mb)	58 $\pm 4$	42 $\pm 3$	94 $\pm 7$	98 $\pm 7$	100 $\pm 7$	108 $\pm 7$	137 $\pm 9$	158 $\pm 10$	182 $\pm 12$	210 $\pm 14$	383 $\pm 25$	393 $\pm 28$	69 $\pm 42$
$\sigma_0^n / (0.06 NZ/A)$	0.24	0.14	0.22	0.21	0.17	0.38	0.40	0.39	0.39	0.36	0.57	0.66	0.6
$E_M$ (MeV)	30	26.7	30	30	29.5	29	30	30	29	30	28.1	26.7	28

METHOD	REF. NO.				
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
E, E/	FMF	1- 6	D 134-250	MAG-D	DST

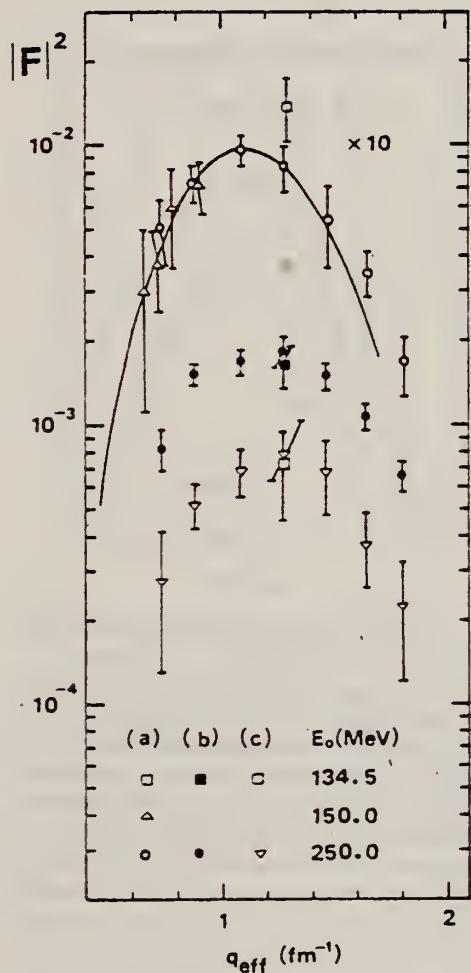


FIG. 7. Experimental squared form factors for (a) the  $1.35\text{-MeV } \frac{1}{2}^+$ , (b)  $5.43\text{-MeV } \frac{1}{2}^+$ , and (c)  $5.63\text{-MeV states in } ^{19}\text{F}$ . The solid curve represents the calculated  $C_3$  form factor Eq. (8) fitted to the data points for the  $1.35\text{-MeV state}$  in the region of  $q < 1.3 \text{ fm}^{-1}$ . From this curve the value of  $B(E3)$  was deduced. The values of the squared form factors for (a) are multiplied by 10 in the figure.

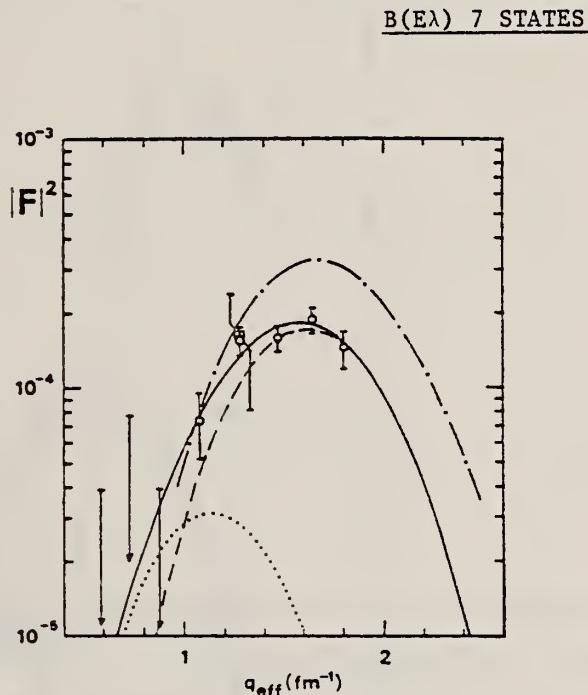


FIG. 8. Squared form factors for the  $4.0\text{-MeV peak}$  which results from the excitations of the  $4.00\text{-MeV } \frac{1}{2}^+$  and  $4.03\text{-MeV } \frac{3}{2}^+$  states. The square denotes the data point at  $E_0 = 134.5 \text{ MeV}$ ,  $\theta = 135^\circ$ . The  $C_3$  and  $C_5$  squared form factors given by Eq. (9) are fitted to experimental data points and shown with the solid curve ( $C_3 + C_5$ ), dotted curve ( $C_3$ ), and dashed curve ( $C_5$ ).  $R = 3.2 \text{ fm}$ ,  $g = 1.0 \text{ fm}$ . The dash-dotted curve represents the calculated  $C_5$  form factor for the  $1g_{9/2}1p_{1/2}$  particle-hole excitation of the doubly closed  $^{16}\text{O}$  core (harmonic oscillator model,  $b = 1.85 \text{ fm}$ ). Vertical lines with arrows indicate upper limits of the experimental form factors.

(over)

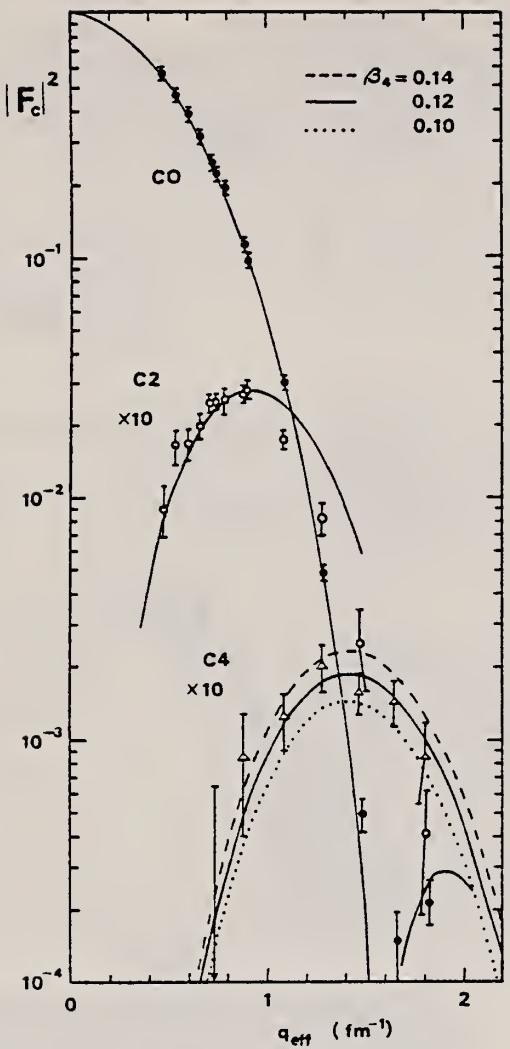


FIG. 9. The  $C_0$ ,  $C_2$  ( $\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$ ), and  $C_4$  ( $\frac{1}{2}^+ \rightarrow \frac{9}{2}^+$ ) squared form factors calculated in the rigid-rotor model using the deformed Fermi distribution with  $c = 2.60$  fm,  $z = 0.527$  fm,  $\beta_2 = 0.43$ , and  $\beta_4 = 0.12 \pm 0.2$ . The experimental points are as follows:  $C_0$ : the ground state (closed circles);  $C_2$ : the 1.55-MeV state (open circles);  $C_4$ : the 2.78-MeV state (triangles, after subtraction of the transverse component). The upper limit of the experimental  $C_4$  form factor at  $q_{\text{eff}} = 0.73$  fm $^{-1}$  is indicated by a vertical line with arrow.

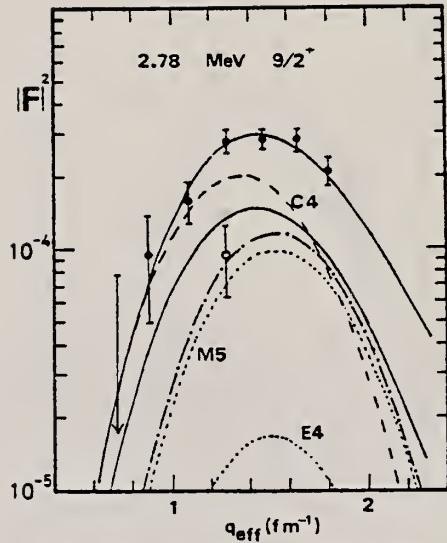


FIG. 12. Experimental and theoretical squared form factors for the 2.78-MeV  $\frac{9}{2}^+$  state in  $^{19}\text{F}$ . The curves are the theoretical values calculated in the RPC model. The closed circles and upper solid curve represent total form factors for  $E_0 = 250$  MeV; the dashed curve is  $C_4$ ; the open circle and the dash-dotted curve are transverse  $E_4 + M_5$ ; the dotted curves are  $E_4$  (lower) and  $M_5$  (upper). The lower solid curve shows the total form factor calculated without RPC using the same parameters as those in the RPC case ( $E_0 = 250$  MeV). A vertical line with arrow indicates the upper limit of the experimental total form factor at  $E_0 = 250$  MeV,  $\theta = 33^\circ$ .

METHOD

REF. NO.

(Page 3 of 4)

75 Oy 1

hmg

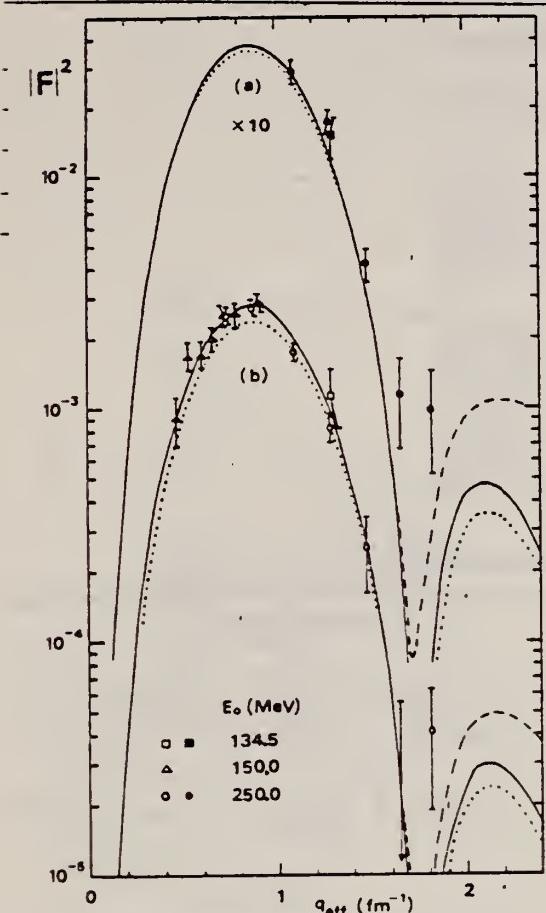


TABLE II. Experimental values of total form factors for negative-parity states in  $^{19}\text{F}$ . Errors are statistical only.

$E_0$ (MeV)	$\theta$ (deg)	$E_x = 1.35$	$ F(q, \theta) ^2 \times 10^4$ $E_x = 4.0$	$E_x = 5.43$	$E_x = 5.63$
134.5	135.0	$13.8 \pm 3.5$	$1.6 \pm 0.8$	$16.3 \pm 2.9$	$7.3 \pm 2.8$
150.0	35.0	$<1.0$			
150.0	40.0	$<1.8$			
150.0	45.0	$<3.0$	$<0.39$		
150.0	50.0	$3.0 \pm 1.9$			
150.0	55.0	$3.7 \pm 1.2$			
150.0	60.0	$5.9 \pm 2.3$			
150.0	70.0	$7.1 \pm 1.5$			
250.0	33.0	$5.0 \pm 1.3$	$<0.77$	$8.2 \pm 1.4$	$2.7 \pm 1.4$
250.0	40.0	$7.3 \pm 1.1$	$<0.39$	$15.1 \pm 1.0$	$5.1 \pm 0.9$
250.0	50.0	$9.5 \pm 1.1$	$0.73 \pm 0.22$	$16.7 \pm 1.6$	$6.8 \pm 1.3$
250.0	60.0	$8.3 \pm 1.5$	$1.54 \pm 0.20$	$18.3 \pm 2.1$	$7.7 \pm 1.6$
250.0	70.0	$5.3 \pm 1.7$	$1.57 \pm 0.18$	$14.9 \pm 1.6$	$6.7 \pm 2.0$
250.0	80.0	$3.50 \pm 0.66$	$1.88 \pm 0.22$	$10.7 \pm 1.1$	$3.7 \pm 1.1$
250.0	90.0	$1.65 \pm 0.39$	$1.44 \pm 0.25$	$6.56 \pm 0.75$	$2.19 \pm 0.97$

(over)

TABLE I. Experimental values of total form factors for positive-parity states in  $^{19}\text{F}$ .  
Errors are statistical only.

$E_0$ (MeV)	$\theta$ (deg)	$ F(q, \theta) ^2$ elastic	$ F(q, \theta) ^2 \times 10^4$ inelastic			
			$E_x = 0.197$	$E_x = 1.55$	$E_x = 2.78$	$E_x = 4.56$
134.5	135.0	$(4.95 \pm 0.46) \times 10^{-3}$	$14.9 \pm 3.1$	$11.3 \pm 3.2$	$8.0 \pm 1.6$	$3.8 \pm 1.3$
150.0	35.0	$(5.71 \pm 0.03) \times 10^{-1}$ <sup>a</sup>		$9.1 \pm 2.5$		
150.0	40.0	$(4.56 \pm 0.05) \times 10^{-1}$ <sup>a</sup>		$16.9 \pm 2.7$		$2.20 \pm 1.04$
150.0	45.0	$(3.88 \pm 0.05) \times 10^{-1}$ <sup>a</sup>		$17.5 \pm 2.8$		$3.21 \pm 0.77$
150.0	50.0	$(3.08 \pm 0.03) \times 10^{-1}$ <sup>a</sup>		$20.0 \pm 2.2$		$3.37 \pm 0.85$
150.0	55.0	$(2.46 \pm 0.02) \times 10^{-1}$ <sup>a</sup>		$25.0 \pm 2.5$		$4.97 \pm 0.93$
150.0	60.0	$(1.97 \pm 0.02) \times 10^{-1}$ <sup>a</sup>		$25.3 \pm 3.1$		$4.87 \pm 0.72$
150.0	70.0	$(1.01 \pm 0.03) \times 10^{-1}$ <sup>a</sup>		$28.5 \pm 2.2$		
250.0	33.0	$(2.26 \pm 0.02) \times 10^{-1}$ <sup>a</sup>		$24.9 \pm 1.9$	$<0.78$	$5.44 \pm 0.58$
250.0	40.0	$(1.17 \pm 0.01) \times 10^{-1}$ <sup>a</sup>		$26.9 \pm 1.4$	$0.94 \pm 0.44$	$4.96 \pm 0.29$
250.0	50.0	$(3.01 \pm 0.05) \times 10^{-2}$	$29 \pm 3$	$17.4 \pm 1.3$	$1.59 \pm 0.32$	$4.02 \pm 0.29$
250.0	60.0	$(4.85 \pm 0.20) \times 10^{-3}$	$17.3 \pm 2.2$	$8.2 \pm 1.2$	$2.80 \pm 0.31$	$2.31 \pm 0.22$
250.0	70.0	$(4.86 \pm 0.75) \times 10^{-4}$	$4.15 \pm 0.68$	$2.5 \pm 0.9$	$2.83 \pm 0.24$	$1.28 \pm 0.17$
250.0	80.0	$(1.47 \pm 0.48) \times 10^{-4}$	$1.15 \pm 0.48$	$<0.55$	$2.84 \pm 0.28$	$1.32 \pm 0.18$
250.0	90.0	$(2.16 \pm 0.45) \times 10^{-4}$	$0.97 \pm 0.45$	$0.41 \pm 0.22$	$2.14 \pm 0.31$	$0.51 \pm 0.18$

<sup>a</sup> Including the 0.197-MeV state component.

TABLE III. Experimental values of electric transition strengths  $J^\pi \rightarrow \frac{1}{2}^+$  (ground state).

Mode	$E_x$ (MeV)	$J^\pi$	Present experiment		Other experiments		
			$B(E\lambda, \emptyset) e^2 \text{ fm}^2 \lambda$ ( $e, e'$ )	$ M ^2$ ( $e, e'$ )	$ M ^2$ Coul. ex.	$(p, p')$	$(d, d')$
$E2$	1.55	$\frac{3}{2}^+$	$24.4 \pm 3.0$	$8.1 \pm 1.0$	$7.84 \pm 0.67$ <sup>a</sup> $5.89 \pm 0.65$ <sup>e</sup>	$9 \pm 3$ <sup>b</sup> $6.8 \pm 0.7$ <sup>f</sup>	$8.4 \pm 0.7$ <sup>c</sup>
$E2$	4.56	$\frac{5}{2}^+$	$3.1 \pm 0.7$	$1.0 \pm 0.2$			
$E3$	1.35	$\frac{5}{2}^-$	$(2.4 \pm 0.6) \times 10^2$	$11 \pm 3$	$12.4 \pm 2.5$ <sup>a</sup> $9.45 \pm 3.43$ <sup>e</sup>	$12 \pm 4$ <sup>b</sup> $7.6 \pm 1.3$ <sup>f</sup>	$1.4 \pm 0.6$ <sup>d</sup>
$E3$	4.00	$\frac{7}{2}^-$	$<8$	$<0.4$			
$E3$	5.43	$\frac{1}{2}^-$	$(3.3 \pm 0.9) \times 10^2$	$15 \pm 4$			
$E4$	2.78	$\frac{3}{2}^+$	$(9.4 \pm 2.0) \times 10^2$	$5.8 \pm 1.3$			
$E5$	4.03	$\frac{9}{2}^-$	$(2.0 \pm 0.9) \times 10^4$	$16 \pm 7$			

<sup>a</sup> Reference 10.

<sup>b</sup> Reference 3.

<sup>c</sup> This value was calculated using the  $\beta_2$  value and Eq. (7) in Ref. 7.

<sup>d</sup> Reference 9.

<sup>e</sup> Reference 11.

<sup>f</sup> Reference 4.

<sup>3</sup> A.E. Litherland, M.A. Clark, C. Broude, Phys. Lett. 3, 204 (1963).

<sup>4</sup> T.K. Alexander, O. Hausser, K.W. Allen, A.E. Litherland, Can. J. Phys. 47, 2335 (1969).

<sup>7</sup> C.M. Crawley, G.T. Garvey, Phys. Rev. 167, 1070 (1968).

<sup>9</sup> D. Dehnhard, N.M. Hintz, Phys. Rev. C1, 460 (1970).

<sup>10</sup> T. Walcher, P. Strehl, Z. Phys. 232, 342 (1970).

<sup>11</sup> P.L. Hallowell et al., Phys. Rev. C7, 1396 (1973).

ELEM. SYM.	A	Z
F	19	9

METHOD

REF. NO.

75 Ts 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, P	ABX	13- 25	D	13- 26	MAG-D		90

Photo cross sections obtained using Barber's El virtual photon spectrum.

CONVERTS TO PHOTO SIG

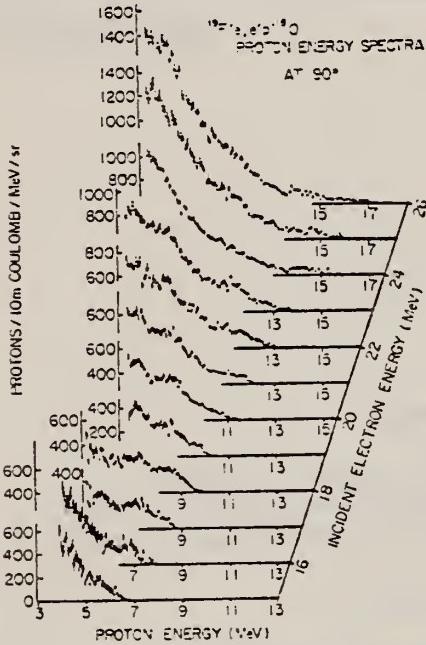


Fig. 2. Proton energy spectra of the  $^{19}\text{F}(\text{e},\text{e}'\text{p})^{18}\text{O}$  reaction at  $90^\circ$ .

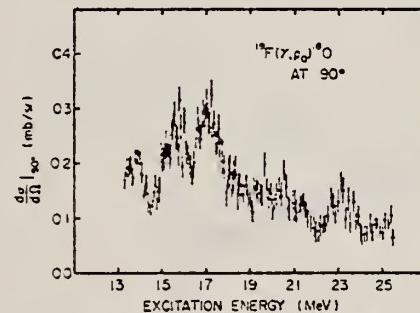


Fig. 4. The  $(\gamma, \text{p})$  differential cross section at  $90^\circ$  for the  $^{19}\text{F}$  nucleus.

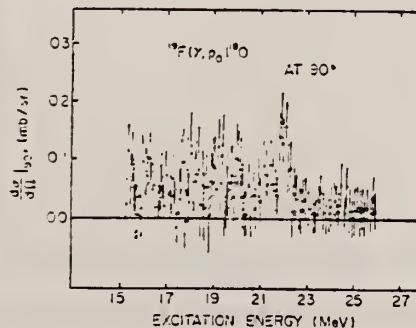


Fig. 5. The  $(\gamma, \text{p})$  differential cross section at  $90^\circ$  for the  $^{19}\text{F}$  nucleus.

Table II. Integrated differential cross sections at  $90^\circ$  (MeV-mb/sr).

	$\int \frac{d\sigma(\gamma, p_i)}{d\Omega} dE$ *	$\int \frac{d\sigma(\gamma, p_i)}{d\Omega} dE$ *	
$^{19}\text{F}$	$25.39$ $1.80 \pm 0.27$	$25.96$ $0.50 \pm 0.45$	present work
	$13.29$	$15.23$	
$^{20}\text{Ne}$	$25.7$ ** $\sim 1.99$ $15.8$ $20.5$ $\sim 2.23$ $16.4$	$~1.99$ $15.8$ $20.5$ $\sim 2.23$ $16.4$	ref. 1 ref. 2

\* Superscripts and subscripts are the limits of integration.

\*\* The integrated differential cross section is calculated from total cross section assuming isotropy.

<sup>1</sup>R. E. Segal et al., Nucl. Phys. A93, 31 (1967).

<sup>2</sup>N. W. Tanner et al., Nucl. Phys. 52, 29 (1964).

ELEM. SYM.	A	Z
F	19	9

METHOD

REF. NO.  
 75 Wo 2 hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N	RLY	16- 40	C	16- 40	ACT-I		4PI

RATIO (G, N) / (E, N)

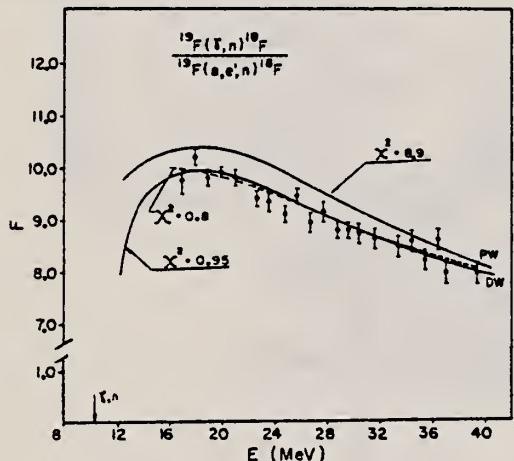


FIG. 2. Measured  $F$  for  $^{19}\text{F}(\gamma, n)$ . Dashed curve is a polynomial fit to the points. Full curves are  $F_{\text{PW}}$  and  $F_{\text{DW}}$  predictions.

$$F_{\text{PW}}^{(\text{PW})} = (N_r / Z_r^2 r_e^2 N_r)$$

$$\times \frac{\int_0^{E_1 - m_q} \sigma_\gamma(\omega) \phi(E_1, \omega, Z_r) (d\omega/\omega)}{\int_0^{E_1 - m_q} \sigma_\gamma(\omega) N_{\text{PW}}^{E_1}(E_1, \omega, Z_r) (d\omega/\omega)}, \quad (10)$$

$$F_{\text{DW}}^{(\text{DW})} = (N_r / Z_r^2 r_e^2 N_r)$$

$$\times \frac{\int_0^{E_1 - m_q} \sigma_\gamma(\omega) \phi(E_1, \omega, Z_r) (d\omega/\omega)}{\int_0^{E_1 - m_q} \sigma_\gamma(\omega) N_{\text{DW}}^{E_1}(E_1, \omega, Z_r) (d\omega/\omega)}, \quad (11)$$

REF.

D. W. Anderson, R. F. Petry, H. J. Fischbeck  
 Nucl. Phys. A262, 91 (1976)

ELEM. SYM.	A	Z
F	19	9
REF. NO.		
76 An 2		egf

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, 2N	ABX	20 - 60	C	19 - 60	ACT-I		4PI

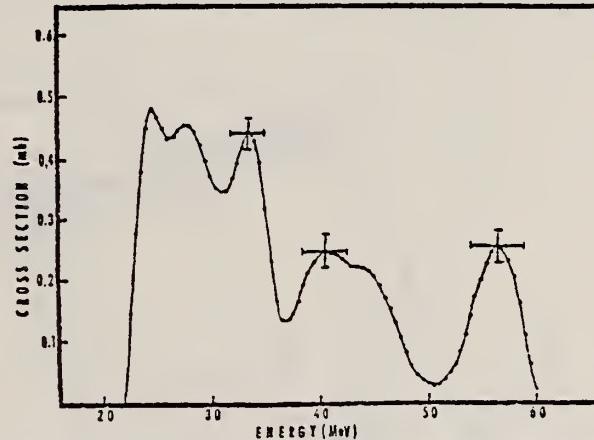


Fig. 2. Cross section for the  $^{19}\text{F}(\gamma, 2\text{n})^{17}\text{F}$  reaction. Vertical bars indicate standard deviations in the cross section. Horizontal bars indicate the minimum width for analysis of a single isolated resonance.

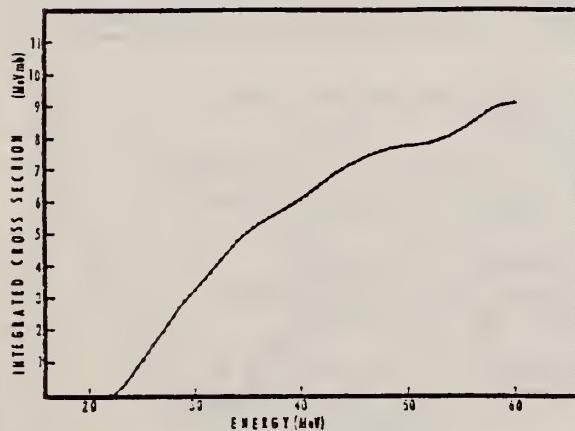


Fig. 3. Integrated cross-section curve for the  $^{19}\text{F}(\gamma, 2\text{n})^{17}\text{F}$  reaction as a function of energy.

ELEM. SYM.	A	Z
F	19	9
REF. NO.		
76 Ma 10		egf

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N13	ABY	THR-999	C	300-999	ACT-I		4PI

999=1 GEV

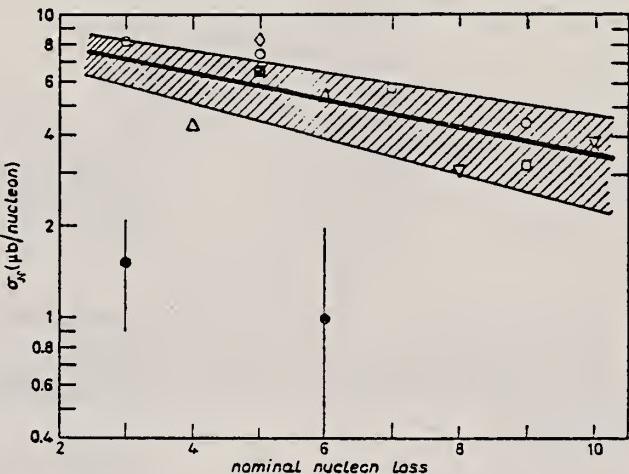


Fig. 1. - Values of mean absolute cross-section per nucleon  $\sigma_N$  as a function of the nominal nucleon loss (semi-logarithmic plot). Open circles:  $^{27}\text{Al}$  target, ref. (1,11,12); open triangles:  $^{28}\text{Si}$  target, ref. (1); open rhomb:  $^{23}\text{Na}$  target, ref. (1); open reversed triangles:  $^{30}\text{S}$  target, ref. (1); open squares:  $^{31}\text{P}$  target, ref. (1); filled square:  $^{18}\text{O}$  target, ref. (1). The straight line is a least-squares fit of all the experimental points. The shaded area represents the standard deviation. Filled circles with error bars: present-work results for  $^{18}\text{O}$  and  $^{19}\text{F}$  targets.

<sup>2</sup>V. Di Napoli and M.L. Terranova: Journal Inorg. Nucl. Chem., 36, 3633 (1974)

<sup>3</sup>V. Di Napoli, G. Rosa, F. Salvetti, M.L. Terranova, H.G. De Carvalho, J.B. Martins and O.A.P. Tavares: Journal. Inorg. Nucl. Chem., 37, 1101 (1975)

<sup>12</sup>V. Di Napoli, A.M. Lacerenza, F. Salvetti, S.M. Terenzi, H.G. De Carvalho and J.B. Martins: Journal Inorg. Nucl. Chem. 35, 1419 (1973)

<sup>16</sup>V. Di Napoli, A.M. Lacerenza, F. Salvetti, H.G. De Carvalho and J.B. Martins: Lett. Nuovo Cimento, 1, 835 (1971)

ELEM. SYM.	A	Z
F	19	9

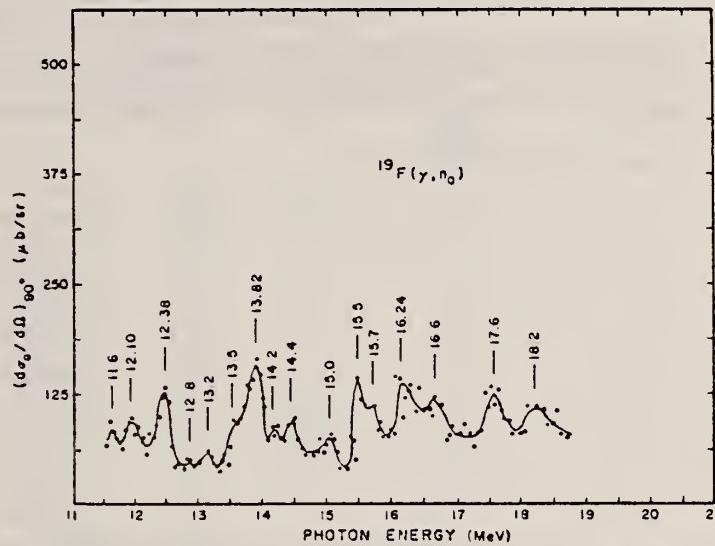
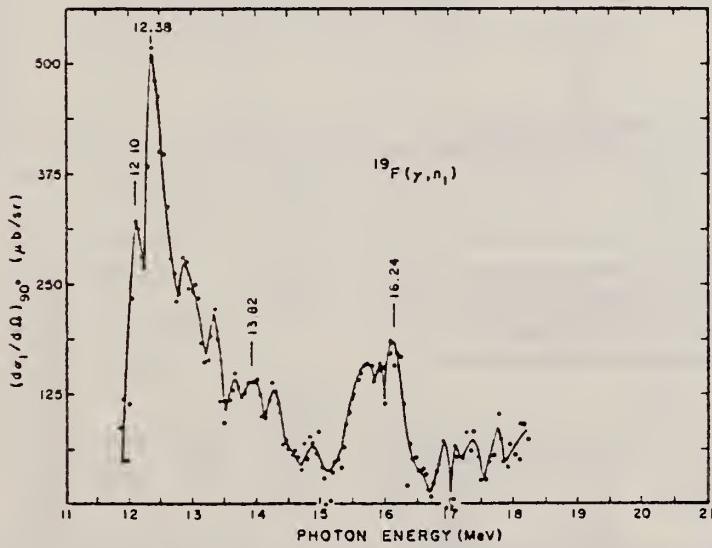
METHOD

REF. NO.

76 Sh 5

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N	ABX	10- 19	C	13- 21	TOF-D		90

FIG. 4. Ground-state photoneutron cross section  $d\sigma_0/d\Omega$  synthesized from the neutron data of Fig. 2, using the photon spectra of Fig. 3.FIG. 5. First-excited-state photoneutron cross section  $d\sigma_1/d\Omega$  obtained from the curves of Fig. 2 after subtracting away the ground-state components.

(over)

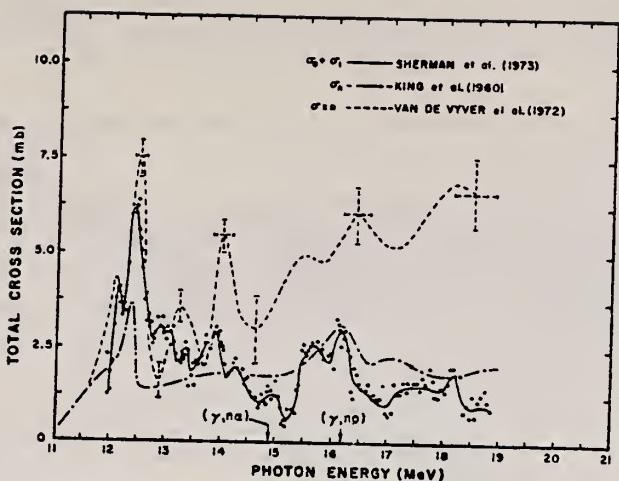


FIG. 6. Comparison of the sum of  $(d\sigma_0/d\Omega) + (d\sigma_1/d\Omega)$  integrated over angle (solid line), with the single-neutron cross section  $\sigma_n$  (dash-dot line) of King *et al.* (1960) and with the total-neutron cross section  $\sigma_{n\gamma}$  (dashed line) of Van de Vyver *et al.* (1972). The angular distribution is assumed to be  $6 + 5 \sin^2 \theta$ .

$$\sigma_{\text{tot}} = 10.66 (\sigma/d\Omega)_{90^\circ}$$

TABLE 1. Correlation of resonances at photon energy  $k$  in the ground-state cross section with observed neutron peaks at energies  $T_{n0}$  and  $T_{n1}$ , ascribed to ground- and first-excited-state transitions. The measured resonance width is  $\Gamma$ , and the  $90^\circ$  branching ratio to the first-excited-state group is  $\sigma_1/\sigma_0$

$k$ (MeV)	$T_{n0}$ (MeV)	$T_{n1}$ (MeV)	$\Gamma$ (keV)	$\sigma_1/\sigma_0$
11.6	1.10	—	(150)	—
12.10 ± 0.04	1.579 ± 0.020	0.64	200 ± 50*	2.46
12.38 ± 0.04	1.842 ± 0.025	0.92	167 ± 50*	3.70
(12.65)	2.10	—	(200)	—
12.79	2.24	—	(200)	(10.1)
13.29	2.71	—	(250)	(3.0)
(13.5)	—	—	—	(1.3)
13.82 ± 0.05	3.22 ± 0.04	2.47	250 ± 100	0.85
(14.2)	—	—	—	—
14.4	3.79	—	(300)	(0.88)
(15.0)	—	—	(550)	(0.75)
15.5	4.64	—	(450)	(2.8)
(15.7)	—	—	—	(0.2)
16.24 ± 0.05	5.49 ± 0.07	4.26	300 ± 150	1.04
16.6	—	—	—	(0.5)
17.6	—	—	—	(0.6)
18.2	—	—	—	—

\*Sherman *et al.* (1972).

TABLE 2. Approximate total integrated cross sections  $\int \sigma_T$  for the principal transitions at photon energies  $k$ . The integrated  $90^\circ$  differential ground-state cross section  $\int d\sigma_0/d\Omega$ , the product of statistical factor  $g$ , and radiative width  $\Gamma_{r0}$ , and the radiative width  $\Gamma_{r0}(\text{E1})$  assuming electric dipole transitions, and spin parity  $J^*$  are also tabulated

$k$ (MeV)	$\int \frac{d\sigma_0}{d\Omega}$		$g, \Gamma_{r0}$ (eV)	$\Gamma_{r0}(\text{E1})$ (eV)	$J^*$
	(MeV mb sr $^{-1}$ )	$\int \sigma_T$ (MeV mb)			
12.10	0.0334	1.21	23.1	11.6	1/2 $^-$
12.38	0.0514	2.53	50.6	25.3	1/2 $^-$
13.82	0.0505	0.98	24.4	24.4	3/2 $^-$
16.24	0.0616	1.32	45.4	45.4	3/2 $^-$

ELEV.	SYM	A	Z
F	19	9	

METHOD				REF. NO.	77 Di 4	egf
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR		
			TYPE RANGE	TYPE RANGE		
A, G	LFT	6 - 7 (6.28-7.17)	D 2-4 (2.87-3.99)	SCD-D		DST

6.28-7.17 MeV

TABLE I  
Resonances in the  $^{15}\text{N} + \alpha$  system in the energy range  $E_x = 2.8\text{-}4.0$  MeV

$E_x$ (keV)	$E_\gamma$ (keV)	$\omega\gamma$ (eV) <sup>b</sup>	From $^{15}\text{N}(\alpha, \gamma)^{19}\text{F}^*$		From $^{15}\text{N}(\alpha, \alpha)^{15}\text{N}^*$	
			$J^\pi$	$I^\pi$	$J^\pi$	$I^\pi$ (lab) (keV)
2873 $\pm$ 3	6281 $\pm$ 2	1.0 $\pm$ 0.2	$\frac{1}{2}^+$	$\frac{1}{2}^+$		3
2935 $\pm$ 3	6330 $\pm$ 2	0.76 $\pm$ 0.15	$\frac{1}{2}^+ (\frac{3}{2}^+)$	$\frac{1}{2}^+$		3
3060 $\pm$ 10	6429 $\pm$ 8			$\frac{1}{2}^-$		358
3146.8 $\pm$ 1.5	6497.4 $\pm$ 1.5	1.7 $\pm$ 0.3	$\frac{3}{2}^+$			
3149.8 $\pm$ 1.5	6499.8 $\pm$ 1.5	2.3 $\pm$ 0.4	$\frac{1}{2}^+$			
3183 $\pm$ 2	6526 $\pm$ 2	2.4 $\pm$ 0.4	$\frac{3}{2}^+$	$\frac{1}{2}^+$		5
3218 $\pm$ 2	6553 $\pm$ 2	0.63 $\pm$ 0.13	$\frac{1}{2}^=$	$\frac{1}{2}^+$		2
3267 $\pm$ 2	6592 $\pm$ 2	1.6 $\pm$ 0.3	$\frac{3}{2}^+$			
3511 $\pm$ 3	6785 $\pm$ 2	10.9 $\pm$ 1.5	$\frac{3}{2}^-$		$\frac{1}{2}^-$	3
3576 $\pm$ 3	6836 $\pm$ 2	1.0 $\pm$ 0.2	$\frac{1}{2}^=$	$\frac{1}{2}^+ (\frac{3}{2}^+)$		1.5
3645 $\pm$ 5	6891 $\pm$ 4	6.1 $\pm$ 1.3	$\frac{1}{2}^-$		$\frac{1}{2}^-$	35
3688 $\pm$ 3	6925 $\pm$ 2	9.7 $\pm$ 1.4	$\frac{1}{2}^=$	$\frac{1}{2}^- (\frac{3}{2}^-)$		3
3770 $\pm$ 10	6989 $\pm$ 8			$\frac{1}{2}^-$		64
3930 $\pm$ 10	7116 $\pm$ 8			$\frac{1}{2}^+$		$\approx 40$
3993 $\pm$ 2	7165.7 $\pm$ 1.0	1.5 $\pm$ 0.2	$\frac{1}{2}^-$			

<sup>a</sup>) This work and refs. <sup>11, 6</sup>).

<sup>b</sup>)  $\omega\gamma = \frac{1}{2}(2J+1)I_2^-\Gamma_\gamma/\Gamma$ . Measured relative to the strength of the  $E_x = 1.68$  MeV resonance <sup>5</sup>).

<sup>c</sup>) Refs. <sup>7, 8</sup>). The  $\alpha$ -particle energies taken from the elastic-scattering work (3.07, 3.78 and 3.94 MeV) have been adjusted downwards by 10 keV to correspond to the other ( $\alpha, \gamma$ ) resonances, and arbitrarily assigned errors of  $\pm 10$  keV.

TABLE 2  
Branching ratios (percentages) for states ( $E_x$  in MeV) in  $^{19}\text{F}$  in the energy range  $E_x = 6.3\text{-}7.2$  MeV

g.s. $\frac{1}{2}^+$	0.11 $\frac{1}{2}^-$	0.20 $\frac{3}{2}^+$	1.35 $\frac{1}{2}^-$	1.46 $\frac{1}{2}^-$	1.55 $\frac{3}{2}^+$	2.78 $\frac{1}{2}^+$	3.91 $\frac{1}{2}^+$	4.00 $\frac{1}{2}^-$	4.03 $\frac{1}{2}^-$	4.38 $\frac{3}{2}^+$	Other
6.28	14 $\pm$ 2		4.2 $\pm$ 1.0	36 $\pm$ 2	26 $\pm$ 2	20 $\pm$ 2					
6.33			56 $\pm$ 3	17 $\pm$ 2		8.5 $\pm$ 1.5					18 $\pm$ 2
6.50	38 $\pm$ 2	14 $\pm$ 2	9 $\pm$ 2	14 $\pm$ 2	25 $\pm$ 2						
6.50						55					4.65 (45 %)
6.53	29 $\pm$ 2	59 $\pm$ 3									4.55 (12 $\pm$ 2 %)
6.55			19 $\pm$ 2	55 $\pm$ 4		26 $\pm$ 3					
6.59			13 $\pm$ 2			63 $\pm$ 3					24 $\pm$ 2
6.79	15 $\pm$ 2	39 $\pm$ 2	13 $\pm$ 2	5.3 $\pm$ 0.8	25 $\pm$ 2		2.6 $\pm$ 1.0				
6.84	9 $\pm$ 5	9 $\pm$ 5	27 $\pm$ 6	10 $\pm$ 7	45 $\pm$ 8						
6.89	9 $\pm$ 2	< 8	< 5	61 $\pm$ 5	30 $\pm$ 5						
6.93			73 $\pm$ 3	22 $\pm$ 2		2.4 $\pm$ 0.5		1.3 $\pm$ 0.5	1.3 $\pm$ 0.5		
7.17								6 $\pm$ 2	94 $\pm$ 2		

(OVER)

TABLE 3  
Angular-distribution coefficients, mixing ratios and some transition strengths for the main  $\gamma$ -decay branches for  $^{19}\text{F}$  states with  $E_{\gamma} = 6.3\text{--}7.0 \text{ MeV}$

$E_1 \rightarrow E_f$	$J_1 \rightarrow J_f$	$A_2/A_0$ <sup>a)</sup>	$A_4/A_0$ <sup>a)</sup>	Mixing ratio, $\delta$ <sup>b)</sup>	$ M ^2$ (W.u.) <sup>c)</sup>
6.28 $\rightarrow$ 0	$\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$	0.612	0.469	$-0.05 \pm 0.07$	$1.9 \pm 0.4$ (E2)
$\rightarrow 1.35$	$\rightarrow \frac{1}{2}^-$	0.468	0.000	$-0.01 \pm 0.09$	$(2.0 \pm 0.4) \times 10^{-3}$ (E1)
$\rightarrow 1.46$	$\rightarrow \frac{1}{2}^-$	-0.350	0.000	$-0.02 \pm 0.04$	$(1.6 \pm 0.3) \times 10^{-3}$ (E1)
$\rightarrow 1.55$	$\rightarrow \frac{1}{2}^+$	-0.617	0.008	$0.11 \pm 0.06$	$0.030 - 0.006$ (M1)
6.33 $\rightarrow$ 0.20	$\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$	0.195	0.045	$-0.27 \pm 0.04$	$0.021 \pm 0.004$ (M1)
					$0.35 \pm 0.10$ (E2)
$\rightarrow 1.35$	$\rightarrow \frac{1}{2}^-$	-0.306	0.000	$-0.02 \pm 0.03$	$(5.4 \pm 1.1) \times 10^{-4}$ (E1)
$\rightarrow 1.55$	$\rightarrow \frac{1}{2}^+$	0.510	-0.367	$0.00 \pm 0.14$	$2.8 \pm 0.6$ (E2)
$\rightarrow 4.38$	$\rightarrow \frac{1}{2}^+$	0.443	-0.001	$0.04 \pm 0.20$	$0.22 \pm 0.05$ (M1)
6.50 $\rightarrow$ 0	$\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$	-0.396		$-0.06 \pm 0.04$	$0.056 \pm 0.010$ (M1)
				or $2.00 \pm 0.17$	$9 \pm 2$ (E2)
$\rightarrow 0.11$	$\rightarrow \frac{1}{2}^-$	-0.507		$0.00 \pm 0.03$	$(9 \pm 2) \times 10^{-4}$ (E1)
$\rightarrow 0.20$	$\rightarrow \frac{1}{2}^+$	0.320		$0.3 - 1.8$	$0.003 - 0.014$ (M1)
					$0.3 - 2.4$ (E2)
$\rightarrow 1.35$	$\rightarrow \frac{1}{2}^-$	-0.236		$-0.11 \pm 0.09$	$(1.8 \pm 0.4) \times 10^{-3}$ (E1)
$\rightarrow 1.46$	$\rightarrow \frac{1}{2}^-$	0.400		$0.00 \pm 0.07$	$(3.4 \pm 0.7) \times 10^{-3}$ (E1)
6.53 $\rightarrow$ 0	$\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$	-0.915		$0.32 \pm 0.04$	$0.053 \pm 0.009$ (M1)
				or $0.90 \pm 0.06$	$5 \pm 1$ (E2)
$\rightarrow 0.11$	$\rightarrow \frac{1}{2}^-$	-0.510		$0.00 \pm 0.02$	$(3.4 \pm 0.9) \times 10^{-3}$ (E1)
$\rightarrow 4.55$	$\rightarrow \frac{1}{2}^+$	-0.368		$-0.23 \pm 0.13$	$20 - 220$ (E2)
	$\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$	-0.371	0.000	$0.01 \pm 0.07$	$0.43 \pm 0.10$ (M1)
6.55 $\rightarrow$ 0.20	$\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$	-0.414	0.001	$0.03 \pm 0.05$	
$\rightarrow 1.35$	$\rightarrow \frac{1}{2}^-$	-0.371	0.000	$0.01 \pm 0.03$	
$\rightarrow 2.78$	$\rightarrow \frac{1}{2}^+$	-0.088	0.000	$0.05 \pm 0.07$	
6.59 $\rightarrow$ 0.20	$\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$	0.633	-0.046	$-0.13 \pm 0.13$	$1.6 \pm 0.4$ (E2)
$\rightarrow 2.78$	$\rightarrow \frac{1}{2}^+$	0.584	-0.022	$-0.20 \pm 0.20$	$0.17 \pm 0.04$ (M1)
$\rightarrow 4.38$	$\rightarrow \frac{1}{2}^+$	-0.369	0.000	$0.02 \pm 0.07$	$0.35 \pm 0.08$ (M1)
6.79 $\rightarrow$ 0	$\frac{1}{2}^- \rightarrow \frac{1}{2}^+$	-0.348		$-0.08 \pm 0.03$	$(5.4 \pm 1.0) \times 10^{-3}$ (E1)
$\rightarrow 0.11$	$\rightarrow \frac{1}{2}^-$	-0.670		$0.11 \pm 0.02$	$0.33 \pm 0.05$ (M1)
					$0.8 \pm 0.3$ (E2)
$\rightarrow 0.20$	$\rightarrow \frac{1}{2}^+$	-0.044		$0.05 \pm 0.06$	$(3.1 \pm 1.1) \times 10^{-3}$ (E1)
$\rightarrow 1.46$	$\rightarrow \frac{1}{2}^-$	0.594		$-0.13 \pm 0.08$	$0.43 \pm 0.07$ (M1)
6.84 $\rightarrow$ 0.20	$\frac{1}{2}^- \rightarrow \frac{1}{2}^+$	0.760	-0.078	$-0.5 \pm 0.5$	
$\rightarrow 1.46$	$\rightarrow \frac{1}{2}^-$	-0.359	0.000	$-0.02 \pm 0.11$	
6.89 $\rightarrow$ 1.35	$\frac{1}{2}^- \rightarrow \frac{1}{2}^-$	0.296		$0.22 - 2.2$	$0.09 - 0.50$ (M1)
					$6 - 120$ (E2)
$\rightarrow 1.46$	$\rightarrow \frac{1}{2}^-$	0.165		$0.15 \pm 0.12$	$0.26 \pm 0.07$ (M1)
6.93 $\rightarrow$ 0.20	$\frac{1}{2}^- \rightarrow \frac{1}{2}^+$	-0.328	0.000	$-0.01 \pm 0.03$	$(12 \pm 2) \times 10^{-3}$ (E1)
$\rightarrow 1.35$	$\rightarrow \frac{1}{2}^-$	-0.371	0.000	$0.01 \pm 0.02$	$0.15 \pm 0.03$ (M1)
$\rightarrow 2.78$	$\rightarrow \frac{1}{2}^+$	-0.172	0.000	$0.00 \pm 0.16$	$(1.7 \pm 0.4) \times 10^{-3}$ (E1)

<sup>a)</sup> The experimental angular distributions are fitted to  $A_0 + A_2 Q_2 P_2 + A_4 Q_4 P_4$ , where  $P_2$  and  $P_4$  are the usual Legendre polynomials, and  $Q_2$  and  $Q_4$  are attenuation coefficients giving the effect of the finite solid angle of the detector (typically 0.90–0.95 and 0.78–0.83, respectively). The fitting procedure requires minimization of  $\chi^2$  with respect to the mixing ratio  $\delta$ , of which  $A_2/A_0$  and  $A_4/A_0$  are known functions.

<sup>b)</sup> The phase convention is that of Rose and Brink <sup>23</sup>). The 68 % errors are assigned by the  $(\chi^2 + 1)$  rule or by the “external-error” method <sup>24</sup>), whichever is larger.

<sup>c)</sup> Weisskopf units as defined by Wilkinson <sup>25</sup>).

METHOD

REF. NO.

78 Di 10

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,C11	ABY	33(33.08)-999	C	300-999	ACT-I		4PI
G,Be7	ABY	30(30.63)-999	C	300-999	ACT-I		4PI

Abstract—Mean cross sections for the photoproduction of  $^7\text{Be}$  and  $^{10}\text{C}$  from  $^{19}\text{F}$ ,  $^{27}\text{Al}$ ,  $^{28}\text{Si}$  and  $^{32}\text{S}$  targets,  $^7\text{Be}$  from  $^{10,11}\text{B}$ , and  $^{10}\text{C}$  from  $^{14}\text{N}$  and  $^{16}\text{O}$  targets have been measured using bremsstrahlung beams in the energy range 0.3–1.0 GeV. The results have been compared with previous measurements and an excellent agreement has been found. In most cases, the values obtained turned out to be much larger than those expected from a simple spallation mechanism. A fragmentation and/or a fission-like process has been suggested in explaining the mechanism of such reactions.

999=1 GEV

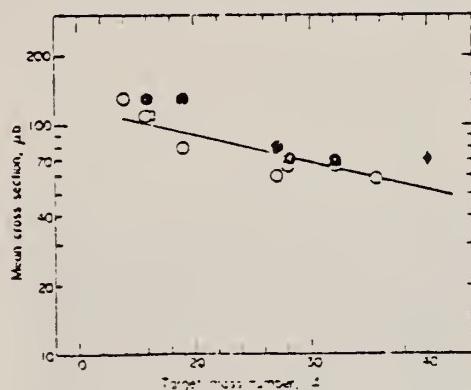


Fig. 1. Mean cross sections per photon,  $\sigma_0$ , of  $^{10}\text{C}$  photoproduction vs the target mass number  $A$ . Experimental data are taken from: ●, Ref. [9]; □, Ref. [13]; ◆, Ref. [2]. ○, present work. The straight line is a least squares fit of the experimental points.

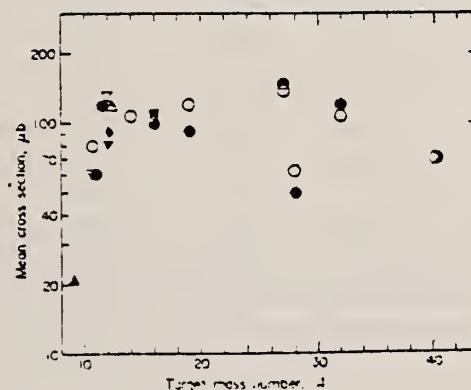


Fig. 2. The same as in Fig. 1 for  $^7\text{Be}$  photoproduction. Experimental data are taken from: ▲, Refs. [6,7]; ▽, Ref. [8]; ○, Ref. [9]; △, Ref. [10]; ◆, Ref. [11]; ▼, Ref. [12]; □, Ref. [13]; ■, Ref. [14]; ♦, Ref. [2]. ○, present work.

Table 1. Cross sections per equivalent quantum of  $^{10}\text{C}$  photoproduction

$E_0$ (GeV)	Cross Section, $\sigma_0$ (μb)					
	$^{14}\text{N}$	$^{16}\text{O}$	$^{19}\text{F}$	$^{27}\text{Al}$	$^{28}\text{Si}$	$^{32}\text{S}$
0.30	520±30	200±20	110±20	28±10	35±10	45±10
0.32	520±30	210±20	120±20	30±10	42±10	50±10
0.35	530±30	230±20	125±20	38±10	45±10	60±10
0.40	530±30	230±20	130±20	42±10	52±10	65±10
0.48	550±30	255±20	150±20	60±10	70±10	80±10
0.55	570±30	250±20	160±20	60±10	78±10	85±10
0.65	600±30	290±20	180±20	70±10	85±10	98±10
0.75	620±30	300±20	180±20	79±10	95±10	110±10
0.90	650±30	320±20	190±20	90±10	110±10	120±10
1.00	680±30	330±20	210±20	100±10	115±10	125±10
						100±10

Table 2. Cross sections per equivalent quantum of  $^7\text{Be}$  photoproduction

$E_0$ (GeV)	Cross Section, $\sigma_0$ (μb)					
	$^{10,11}\text{B}$	$^{14}\text{N}$	$^{16}\text{O}$	$^{19}\text{F}$	$^{27}\text{Al}$	$^{28}\text{Si}$
0.30	150±20	200±20	113±20	152±20	40±20	20±20
0.32	160±20	200±20	120±20	150±20	45±20	20±20
0.35	160±20	210±20	130±20	159±20	42±20	30±20
0.40	175±20	225±20	145±20	170±20	98±20	20±20
0.48	190±20	245±20	163±20	186±20	100±20	50±20
0.55	200±20	260±20	187±20	200±20	93±20	48±20
0.55	220±20	280±20	197±20	214±20	140±20	68±20
0.75	225±20	300±20	215±20	227±20	180±20	70±20
0.90	240±20	318±20	230±20	245±20	186±20	88±20
1.01	250±20	330±20	242±20	260±20	200±20	97±20
						190±20

Table 3. Comparison between experimentally determined and calculated cross sections of  ${}^7\text{Be}$  and  ${}^{11}\text{C}$  photo-production and indication of the dominant reaction channels

Target Nucleus	Product Nucleus	Nominal Nuclear Loss, $\Delta A/A_t$ ( $\times 10^{-4}$ )	$\bar{\sigma}_{\text{exp}}^{(*)}$ (nb)	$\bar{\sigma}_{\text{CDMO}}^{(**)}$ (nb)	$\frac{\bar{\sigma}_{\text{exp}}}{\bar{\sigma}_{\text{CDMO}}}$	Apparent Threshold (Exp.)	Possible Mechanism of Production	
						$E_{\text{th}}$ (MeV)		
${}^{10,11}\text{B}$	${}^7\text{Be}$	(3), (30), 36	67	28	2	$\leq 50$	Spallation	
${}^{12}\text{C}$	${}^7\text{Be}$	5	42	110	20	5	$\leq 50$	Spallation
${}^{14}\text{N}$	${}^7\text{Be}$	7	50	108	12	9	$\leq 50$	Fission Spallation
${}^{14}\text{N}$	${}^{11}\text{C}$	3	21	130	60	2	$\leq 50$	Spallation
${}^{16}\text{O}$	${}^7\text{Be}$	9	56	107	8	13	$50 < E_{\text{th}} < 200$	Fission Fragmentation
${}^{16}\text{O}$	${}^{11}\text{C}$	5	31	117	33	3	$\leq 50$	Spallation
${}^{19}\text{F}$	${}^7\text{Be}$	12	63	106	5	21	$50 < E_{\text{th}} < 200$	Fission Fragmentation
${}^{19}\text{F}$	${}^{11}\text{C}$	8	42	105	16	7	$50 < E_{\text{th}} < 200$	Fission Fragmentation Spallation
${}^{27}\text{Al}$	${}^7\text{Be}$	20	74	142	2	71	$> 200$	Fragmentation
${}^{27}\text{Al}$	${}^{11}\text{C}$	16	59	70	5	14	$50 < E_{\text{th}} < 200$	Fission Fragmentation
${}^{28}\text{Si}$	${}^7\text{Be}$	21	75	56	2	28	$> 200$	Fragmentation
${}^{28}\text{Si}$	${}^{11}\text{C}$	17	61	68	4	17	$50 < E_{\text{th}} < 200$	Fission Fragmentation
${}^{32}\text{S}$	${}^7\text{Be}$	25	78	114	2	57	$> 200$	Fragmentation
${}^{32}\text{S}$	${}^{11}\text{C}$	21	66	68	3	23	$50 < E_{\text{th}} < 200$	Fission Fragmentation
${}^{35,37}\text{Cl}$	${}^{11}\text{C}$	24, (26), 69, (70)	59	3	20	$50 < E_{\text{th}} < 200$	Fission Fragmentation	
${}^{40}\text{Ca}$	${}^7\text{Be}$	33	83	70	1	70	$> 200$	Fragmentation
${}^{40}\text{Ca}$	${}^{11}\text{C}$	29	73	70	2	35	$> 210$	Fragmentation

(\*) Mean values of the different measurements (see Figs. 1 and 2).

(\*\*) Calculated values according to Ref. [8].

REF. T.J.M. Symons, L.K. Fifield, M.J. Hurst, F. Watt, C.H. Zimmerman  
and K.W. Allen  
J. Phys. G 4, 411 (1978)

ELEM. SYM.	A	Z
F	19	9

METHOD

REF. NO.

78 Sy 2

rs

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
A,G	LFT	8- 10	D	5- 8	SCD-D		55

**Abstract.** The  $^{15}\text{N}(\alpha, \gamma)^{19}\text{F}$  reaction has been studied for  $\alpha$ -particle bombarding energies from 5.2 to 8.4 MeV using a differentially-pumped gas target. Forty-two resonances have been identified in the gamma ray yield, of which 32 have been observed to decay by gamma emission to known states in  $^{19}\text{F}$ . The remaining ten resonances were found to arise from the  $^{15}\text{N}(\alpha, \gamma)^{15}\text{N}$  and  $^{15}\text{N}(\alpha, p)^{18}\text{O}$  reactions. Decay schemes, widths and values of  $\epsilon/\gamma$  have been measured for many of these states. The data obtained are compared with previous published work on the  $^{19}\text{F}$  nucleus.

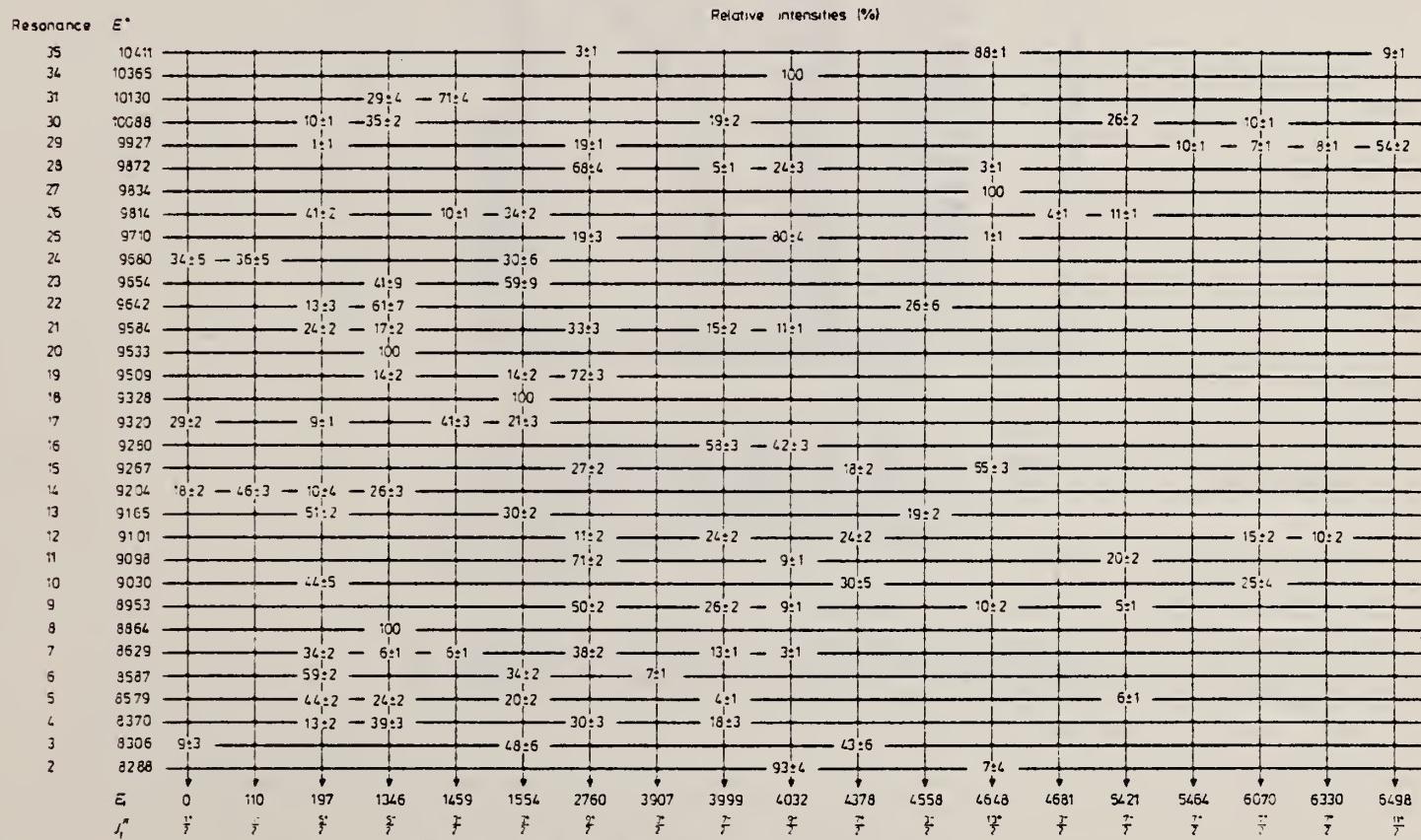


Figure 6. Relative intensities at 55° of the decays of resonances observed in the  $^{15}\text{N}(\alpha, \gamma)^{19}\text{F}$  reaction.

Table 1. Properties of capture resonances.

Resonance	$E^*$ (keV)	$E_x$ (keV)	$\Gamma$ (keV)	$\omega\gamma(55^\circ)$ (eV)	$J^\pi$
2	8288 ± 4	5415 ± 5	<1	0.58 ± 0.1	$\frac{1}{2}^-$
3	8306 ± 4	5439 ± 5	<1	2.1 ± 0.5	$\frac{3}{2}^+$
4	8370 ± 4	5520 ± 5	7.5 ± 1.5	0.54 ± 0.2	$\frac{1}{2}, \frac{3}{2}^+$
5	8579 ± 4	5784 ± 5	~1	5.1 ± 1.3	$\frac{1}{2}$
6	8587 ± 3	5794 ± 4	2.1 ± 0.1*	1.6 ± 0.35	$\frac{3}{2}^+$
7	8629 ± 4	5487 ± 5	<1	2.5 ± 0.4	$\frac{7}{2}^+$
8	8864 ± 4	6145 ± 5	<1	0.2 ± 0.05	$\Delta \frac{9}{2}^+$
9	8953 ± 3	6261 ± 4	~1	0.85 ± 0.2	$\frac{1}{2}^-, (\frac{5}{2}^+)$
10	9030 ± 5	6356 ± 5	4.2 ± 1	0.53 ± 0.26	$\frac{1}{2}, \frac{7}{2}$
11	9098 ± 4	6442 ± 5	0.57 ± 0.03*	0.48 ± 0.15	$\frac{7}{2}^+$
12	9101 ± 4	6445 ± 5	~1	0.40 ± 0.1	$\frac{7}{2}, \frac{9}{2}$
13	9165 ± 5	6526 ± 6	9.9 ± 1.5	1.4 ± 1	$\frac{1}{2}, \frac{3}{2}$
14	9204 ± 7	6576 ± 6	10.2 ± 1.5	1.5	$\frac{3}{2}$
15	9267 ± 4	6656 ± 5	2 ± 1	0.15 ± 0.04	$\frac{1}{2}^+, \frac{3}{2}^+$
16	9280 ± 5	6672 ± 6	<1.5	0.38 ± 0.09	$\frac{5}{2}, \frac{9}{2}$
17	9320 ± 4	6722 ± 5	3.4 ± 1	3.4 ± 1.7	$\frac{1}{2}^+$
18	9329 ± 4	6735 ± 5	~6	—	$\Delta \frac{9}{2}^+$
19	9509 ± 4	6963 ± 5	<1	0.7 ± 0.2	$\frac{3}{2}^+, \frac{7}{2}^+$
20	9533 ± 6	6993 ± 7	6.3 ± 1.5	0.5	$\frac{1}{2}, \frac{5}{2}$
21	9584 ± 4	7057 ± 5	9.6 ± 1.5	5.2 ± 3	$\frac{7}{2}$
22	9642 ± 6	7131 ± 7	~8	~1	$\frac{3}{2}, \frac{5}{2}$
23	9654 ± 6	7146 ± 6	~6	~2	$\frac{3}{2}, \frac{5}{2}$
24	9680 ± 6	7179 ± 7	~4	~1	$\frac{1}{2}, \frac{3}{2}$
25	9710 ± 4	7217 ± 5	<1	4 ± 0.7	$\frac{9}{2}^+, \frac{11}{2}$
26	9814 ± 4	7349 ± 5	<1.5	3.5 ± 0.8	$\frac{3}{2}^+$
27	9834 ± 3	7376 ± 4	<1	0.51 ± 0.1	$\frac{1}{2}, \frac{13}{2}, \frac{15}{2}$
28	9872 ± 3	7422 ± 4	~1.5	3.6 ± 0.6	$\frac{9}{2}^+, \frac{11}{2}^-$
29	9926 ± 3	7491 ± 4	~1	19.3 ± 3.0	$\frac{9}{2}^+$
30	10088 ± 5	7696 ± 6	<1.5	2.37 ± 0.5	$\frac{5}{2}, \frac{7}{2}$
31	10130 ± 6	7749 ± 6	3.2 ± 1	1.3 ± 0.4	$\frac{3}{2}, \frac{5}{2}$
34	10365 ± 4	8047 ± 5	3 ± 1.5	0.9 ± 0.4	$\frac{1}{2}, \frac{3}{2}, \frac{11}{2}$
35	10411 ± 3	8105 ± 4	<1.5	15.0 ± 3.0	$\frac{11}{2}^+, \frac{13}{2}^+$

\* These values are from the measurements of Yagi (1962).

Yagi, K. 1962, J. Phys. Soc. Japan 17, 604.

REF. C.F. Williamson, F.N. Rad, S. Kowalski, J. Heisenberg, H. Crannell,  
 J.T. O'Brien, and H.C. Lee  
 Phys. Rev. Lett. 40, 1702 (1978)

ELEM. SYM.	A	Z
F	19	9

METHOD	REF. NO.				
	78 Wi 2	rs			
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
E,E/	FMF	0- 5	D    1* 3	MAG-D	DST

Cross sections for the electroexcitation of the ground-state rotational band in  $^{19}\text{F}$  have been measured over the momentum transfer range  $0.5 \leq q \leq 2.5 \text{ fm}^{-1}$  and are compared to calculations based on the variation-after-projection, Hartree-Fock approximation. The data support the predicted predominance of  $\vec{L} \cdot \vec{S}$  coupling for this band. The 546-keV level is unambiguously identified as the  $\frac{1}{2}^+$  member of the ground-state band.

\*Q=0.5-2.5FM-1

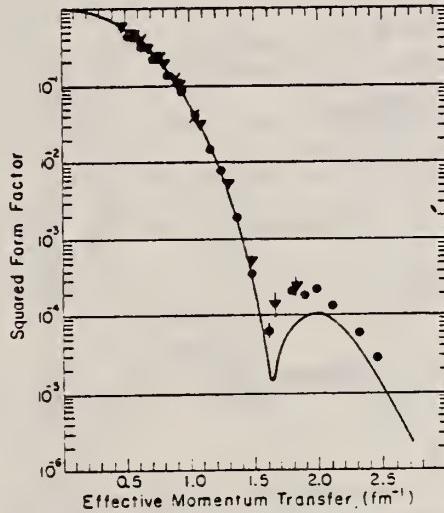


FIG. 1. Squared form factors for elastic scattering in  $^{19}\text{F}$ . Solid circles, present data; crosses, data of Ref. 1; inverted triangles, data of Ref. 2; solid line, VPHF calculation.

<sup>2</sup>M. Oyamada, T. Terasawa, K. Nakahara, Y. Endo,  
 H. Saito, E. Tanaka, Phys. Rev. C 11, 1578 (1975).

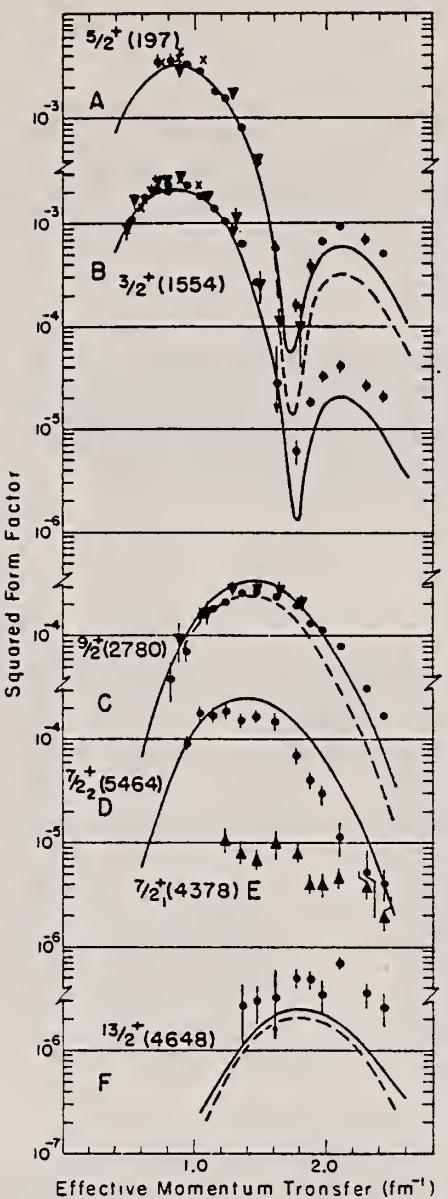


FIG. 2. Squared form factors for inelastic scattering in  $^{19}\text{F}$ . Circles and triangles, present data; crosses, data of Ref. 1; inverted triangles, data of Ref. 2; solid line, VPHF calculation including both longitudinal and transverse magnetic components; in B and D the magnetic components are predicted to be negligibly small; dashed line, VPHF calculation including longitudinal components only.

<sup>1</sup>P.L. Hallowell, W. Bertozzi, J. Heisenberg, S. Kowalski, X. Maruyama, C.P. Sargent, W. Turchinetz, C.F. Williamson, S.P. Fivozinsky, J.W. Lightbody, Jr., and S. Penner, Phys. Rev. C 7, 1346 (1973).

<sup>2</sup>M. Oyamada, T. Terasawa, K. Nakahara, Y. Endo, H. Saito, E. Tanaka, Phys. Rev. C 11, 1578 (1975).

ELEM. SYM.	A	Z
F	19	9

METHOD

REF. NO.

79 Th 1

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,PG	ABX	14-30	C	14-30	SCD-D		150
G,NG							
G,AG							

Abstract: Cross sections and integrated cross sections for photodisintegration of  $^{19}\text{F}$  to excited residual states following emission of protons, neutrons and  $\alpha$ -particles have been measured. The size of the photo- $\alpha$  cross sections appear to be too large to be explained by a semidirect reaction mechanism.

### DE-EXCIT G-RAYS

E NUCLEAR REACTIONS  $^{19}\text{F}(\gamma, n)$ ,  $^{19}\text{F}(\gamma, p)$ ,  $^{19}\text{F}(\gamma, \alpha)$ , bremsstrahlung  $E_{\text{max}} = 14-30$  MeV; measured  $\sigma$ ,  $\int d\sigma/dE$ , de-excitation  $\gamma$ -rays,  $^{18}\text{F}$ ,  $^{18}\text{O}$ ,  $^{15}\text{N}$  deduced levels,  $J$ ,  $\pi$ . Natural target.

TABLE I

Cross sections integrated to 30 MeV for photoreaction in  $^{19}\text{F}$  leading to the levels indicated

Level (MeV)	$J^{\pi}, T$	$\int_{14}^{30} \left( \frac{d\sigma}{d\Omega} \right)_{150^{\circ}} dE$	$\int_{14}^{30} \left( \frac{d\sigma}{d\Omega} \right)_{150^{\circ}} dE$	Rel. strength following irradiation with 14 MeV bremsstrahlung <sup>1)</sup>
		this work (MeV · mb/sr)	ref. <sup>a)</sup> (MeV · mb/sr)	
$^{18}\text{O}$				
1.982	$2^+, 1$	$1.6 \pm 0.2^b)$	1.75	$158 \pm 10$
3.553	$4^+, 1$	$< 0.1$		
3.632	$0^-, 1$	$0.4 \pm 0.2^b)$	0.90	$38 \pm 11$
3.919	$2^+, 1$	$0.2 \pm 0.1^b)$		
4.448	$1^-, 1$	$0.6 \pm 0.2^b)$		$20 \pm 10$
$^{19}\text{F}$				
0.936	$3^+, 0$	$1.0 \pm 0.2^b)$	1.25	
1.042	$0^-, 1$	$0.9 \pm 0.2^b)$	0.45	
1.081	$0^-, 0$	$0.2 \pm 0.1^b)$		
1.128	$5^+, 0$	?		
1.701	$1^+, 0$	$< 0.05$		
2.101	$2^-, 0$	$< 0.1^b)$		
2.524	$2^+, 0$	$\leq 0.04^b)$		
3.059	$2^+, 1$	$0.3 \pm 0.15^b)$		
3.135	$1^-, 0$	$0.3 \pm 0.1^b)$		
4.739	$3^+, 0$	$0.07 \pm 0.02^b)$		
$^{15}\text{N}$				
5.270	$\frac{1}{2}^+$	$0.1 \pm 0.03^b)$		$71 \pm 2$
5.270				
<sup>a)</sup>	$(\frac{1}{2}^+ + \frac{1}{2}^+)$	$0.33 \pm 0.13^b)$	0.75	$184 \pm 6$
5.299				

<sup>a)</sup> Evaluated by direct integration of cross section.

<sup>b)</sup> Evaluated from yield at 30 MeV.

<sup>c)</sup> Evaluated by comparing the strength of the peaks to that from 1.98 MeV level in  $^{18}\text{O}$  in summed spectrum.

(OVER)

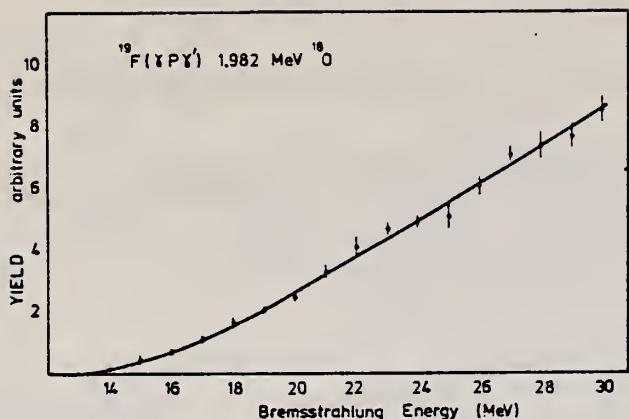


Fig. 2a. The yield curve for the photoreaction  $^{19}\text{F}(\gamma, \text{p})$  to the 1.982 MeV state in  $^{18}\text{O}$

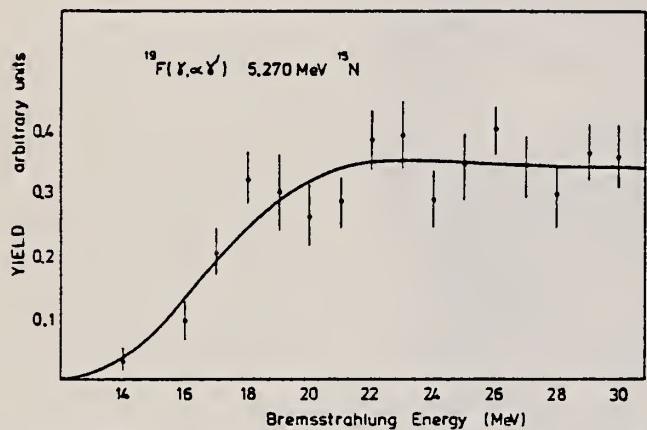


Fig. 2b. The yield curve for the photoreaction  $^{19}\text{F}(\gamma, \text{z})$  to the 5.270 MeV state in  $^{15}\text{N}$ .

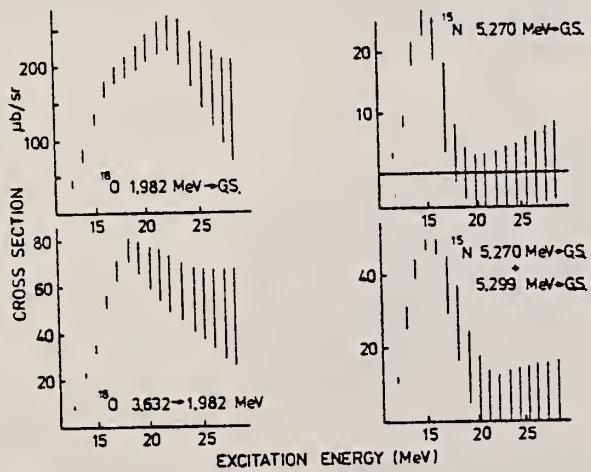


Fig. 3. Cross sections for photoreactions in  $^{19}\text{F}$  leading to the emission of the de-excitation  $\gamma$ -rays indicated. No corrections for feeding from higher states has been made to those data.

ELEM. SYM.	A	Z
F	19	9

METHOD

REF. NO.

80 Ca 4

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
\$ P,G	ABX	15-23	D	3-10	NAI-D		DST

### \$ POLARIZED PROTONS

The striking intermediate structure observed in the giant E1 resonance of  $^{20}\text{Ne}$  has been studied with the polarized and unpolarized  $^{19}\text{F}(\vec{p}, \gamma_0)^{20}\text{Ne}$  reaction. A heuristic model of four intermediate doorway resonances is found to fit the data.

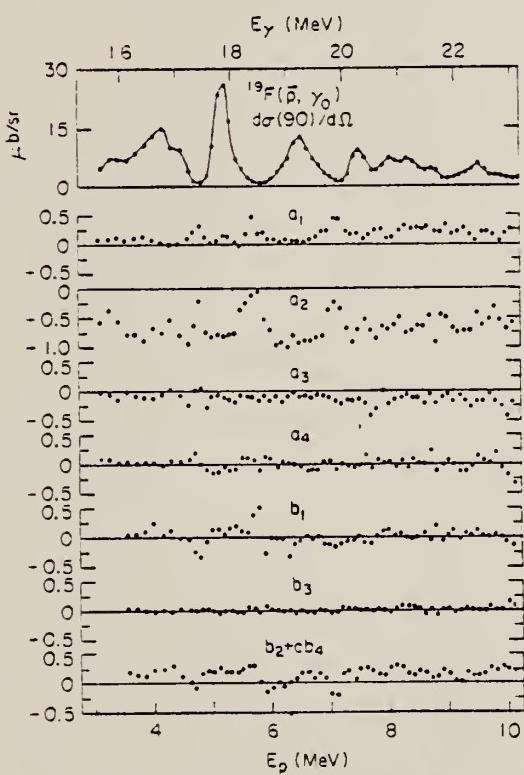


Fig. 1. Shown from the top to bottom are the observed differential cross sections of  $^{19}\text{F}(\vec{p}, \gamma_0)^{20}\text{Ne}$  at  $90^\circ$  along with the angular distribution coefficients discussed in the text.

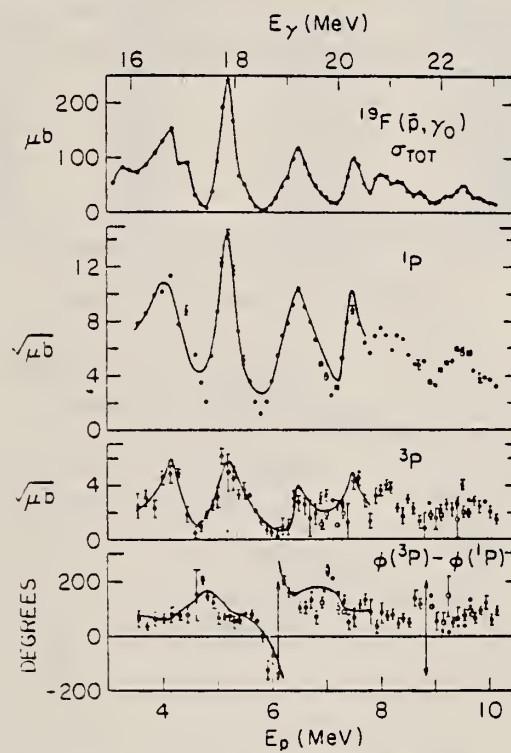


Fig. 2. Shown from top to bottom are the extracted total  $(\vec{p}, \gamma_0)$  cross sections, the  $^1\text{P}$  and  $^3\text{P}$  amplitudes, normalized so that  $|^1\text{P}|^2 + |^3\text{P}|^2 = \sigma(\vec{p}, \gamma_0)$ , and the relative phase. To keep the plotted values of these phases between  $\pm\pi$  they are changed by  $2\pi$  at the discontinuity. Indefinite values are indicated by the vertical double arrows. The top curve is simply drawn through the points. The other curves are fits obtained with the four-resonance model discussed in the text.

ELEM. SYM.	A	Z
F	19	9

METHOD	REF. NO.
	80 Ya 2
	hg
REACTION	RESULT
G,Fl8	YLD
	THR-60
	C 30-60
	ACT-I
	4PI

The production rates of  $^{18}\text{F}$  by the  $^{20}\text{Ne}(\gamma, pn)^{18}\text{F}$  plus  $^{20}\text{Ne}(\gamma, 2n)^{18}\text{Ne} \rightarrow ^{18}\text{F}$ ,  $^{23}\text{Na}(\gamma, 2n)^{18}\text{F}$ , and  $^{19}\text{F}(\gamma, n)^{18}\text{F}$  reactions were determined as a function of the maximum bremsstrahlung energies between 30 and 60 MeV. In addition, a simple and fast method to prepare anhydrous  $\text{H}^{18}\text{F}$  was studied by using  $\text{KHF}_2$  target.

TABLE I. Photonuclear reactions for  $^{18}\text{F}$  production

Target nuclide (abundance, %)	Reaction type	Threshold energy (MeV)	Product nuclide
$^{20}\text{Ne}$ (90.51)	$(\gamma, 2n)$	28.50	$^{18}\text{Ne} \rightarrow ^{18}\text{F}$
$^{21}\text{Ne}$ (0.27)	$(\gamma, 3n)$	35.27	$^{18}\text{Ne} \rightarrow ^{18}\text{F}$
$^{22}\text{Ne}$ (9.22)	$(\gamma, 4n)$	45.63	$^{18}\text{Ne} \rightarrow ^{18}\text{F}$
$^{20}\text{Ne}$ (90.51)	$(\gamma, pn)$	23.26	$^{18}\text{F}$
$^{21}\text{Ne}$ (0.27)	$(\gamma, p2n)$	29.93	$^{18}\text{F}$
$^{22}\text{Ne}$ (9.22)	$(\gamma, p3n)$	40.38	$^{18}\text{F}$
$^{23}\text{Na}$ (100)	$(\gamma, 2n)$	20.89	$^{18}\text{F}$
$^{19}\text{F}$ (100)	$(\gamma, n)$	10.43	$^{18}\text{F}$

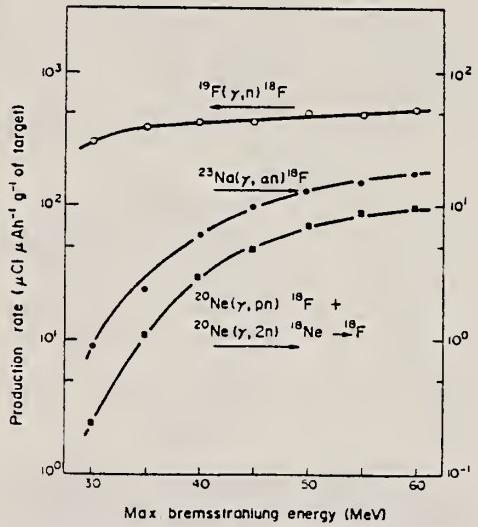


FIG. 1. Production rates of  $^{18}\text{F}$  on Ne, Na and F targets as a function of the maximum bremsstrahlung energy.

F  
A=20

F  
A=20

F  
A=20



METHOD

REF. NO.

67 Be 7

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
N, G	LFT	6-7	D	0-1	NAI-D	0-7	90

SOURCE 27,50 KEV

TABLE I. Gamma rays from  $^{19}\text{F}(\text{n},\gamma)^{20}\text{F}$ ;  $E_{\text{n}} = 27 \text{ keV}$ ,  $J^{\pi} = 2^-$ .

$E_{\gamma}$ (MeV)	$I_{\gamma}$ (per 100 captures)	Assignment	$J_i^{\pi} \rightarrow J_f^{\pi}$	$\Gamma_{\gamma_i}$ (meV)	$1000 M ^2$
5.98	6±2	$C \rightarrow 0.65$	$2^- \rightarrow (2,3)^+$	65	0.6
5.31	32±2	$C \rightarrow 1.31$	$2^- \rightarrow 2^+$	350	4.6
4.66	50±2	$C \rightarrow 1.97 (C \rightarrow 1.85)$	$2^- \rightarrow ?, (2^- \rightarrow ?)$	550	11
(4.09)*	(4)	(4.08 → 0)	$[(0,1)^+ \rightarrow 2^+]$		
3.5	4±2	(3.5 → 0)			
3.1	8±1	(C → 3.55, 3.49, 3.59)		(90)	
2.60	5±2	$C \rightarrow 4.08$	$[2^- \rightarrow (0,1)^+]$	55	6
1.98	8±3	1.97 → 0	? → 2 <sup>+</sup>		
1.85	15±4	1.85 → 0	? → 2 <sup>+</sup>		
1.32	57±2	{ 1.31 → 0	{ 2 <sup>+</sup> → 2 <sup>+</sup>		
		{ 1.97 → 0.65	{ ? → (2,3) <sup>+</sup>		
1.15	16±2	1.97 → 0.83	? → (1,2,3) <sup>+</sup>		
(0.95)*	(4)	(1.06 → 0, 0.99 → 0)			
0.84	4±2	0.83 → 0	$(1,2,3)^+ \rightarrow 2^+$		
0.65	~30	0.65 → 0	$(2,3)^+ \rightarrow 2^+$		

\* Parentheses imply marginal credibility.

TABLE II. Gamma rays from  $^{19}\text{F}(\text{n},\gamma)^{20}\text{F}$ ;  $E_{\text{n}} = 50 \text{ keV}$ ,  $J^{\pi} = 1^-$ .

$E_{\gamma}$ (MeV)	$I_{\gamma}$ (per 100 captures)	Assignment	$J_i^{\pi} \rightarrow J_f^{\pi}$	$\Gamma_{\gamma_i}$ (meV)	$1000 M ^2$
6.60(?)	5±3	$C \rightarrow 0$	$1^- \rightarrow 2^+$	80	0.6
6.0	9	$C \rightarrow 0.65$	$1^- \rightarrow (2,3)^+$	~140	~1.3
* 5.6	13	$34 \pm 3$	$C \rightarrow 0.99$	(~200)	
			1.06		
5.35	12	$C \rightarrow 1.31$	$1^- \rightarrow 2^+$	~190	
4.60	42±2	{ $C \rightarrow 2.05$	$1^- \rightarrow (1,2,3)^+$	670	~2.5
		{ $(C \rightarrow 1.97 \text{ weak})$			
3.7	13±3	{ (3.59)			
3.5		{ 3.53 → 0			
		{ (3.49)			
3.09	20±2	(C → 3.59, 3.53)		(320)	
2.5-2.6	7±3	{ 3.59 → { 0.65 } }			
		{ 3.53 → { 0.99 }			
2.1	8±3	3.49 → { 0.83 }			
1.9	6±3	2.05 → 0	$(1,2,3)^+ \rightarrow 2^+$		
1.38	37±3	{ 2.05 → 0.65			
		{ (1.31 → 0) <sup>b</sup>			
		{ (1.97 → 0.65)			
1.15	3±2	1.97 → 0.83			
* 1.06	7±3	1.06 → 0	$(0,1)^+ \rightarrow 2^+$		
0.9-1.0	6±3	0.65 → 0	$(2,3)^+ \rightarrow 2^+$		
0.65	≥30				

\* Unresolved structure.

\* Parentheses imply marginal credibility.



## NEON

 $Z=10$ 

Neon (Greek *neos*, new) was discovered by Sir William Ramsay (1852-1916), and his assistant Morris William Travers. Argon and helium had been discovered with atomic weight of 40 and 4 respectively; Ramsay thought there might be an intermediate gas with an atomic weight of 20. Ramsay and Travers tried, unsuccessfully, to find this gas by heating rare minerals. The rare gases could not be detected by chemical means since they are inert and they could not be detected by spectroscopy because of their high dilution in air. It was first necessary for them to remove the carbon dioxide, oxygen, and nitrogen by chemical means. Next they liquified and then solidified the argon by surrounding it with liquid air under reduced pressure. They then allowed the argon to volatize and collected the portion that distilled off first. The vacuum tube containing this volatile fraction of gas was subject to the Plücker tube for spectroscopic analysis. The blaze of crimson light (now so familiar to us as the light from a neon tube) convinced them that they had discovered a new gas.



ELEM. SYM.	A	Z
Ne		10
REF. NO.	54 Fe 1	rs

METHOD	REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
				TYPE	RANGE	
	G,SN	ABX	10-25	C	11-25	BF3-I
						4PI

The direct detection of neutrons from ( $\gamma, n$ ) reactions induced by betatron bremsstrahlung has been applied to cross-section determinations using gaseous targets at approximately 100 atmospheres pressure. Results from oxygen are consistent with other determinations. The remaining elements represent new results and show the familiar giant dipole resonance for the photoneutron process. Parameters of the resonances are determined and related to the systematic behavior previously reported for other elements.

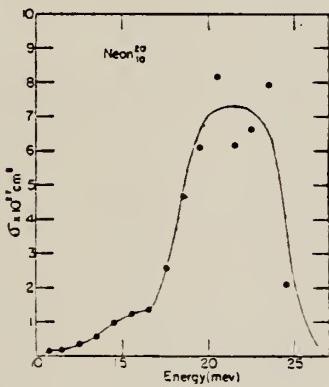


FIG. 8. Photoneutron excitation function for neon.

<sup>1</sup>Horsley, Haslam, and Johns, Phys. Rev. 87, 756 (1952).  
<sup>2</sup>R. Nathans and J. Halpern, Phys. Rev. 92, 940 (1953).

METHOD					REF. NO.		
Linac; counted delayed neutrons from N <sup>17</sup>					55 Re 1	NVB	
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N17	ABI	THR - 400	C	90-400	ACT-I		4PI

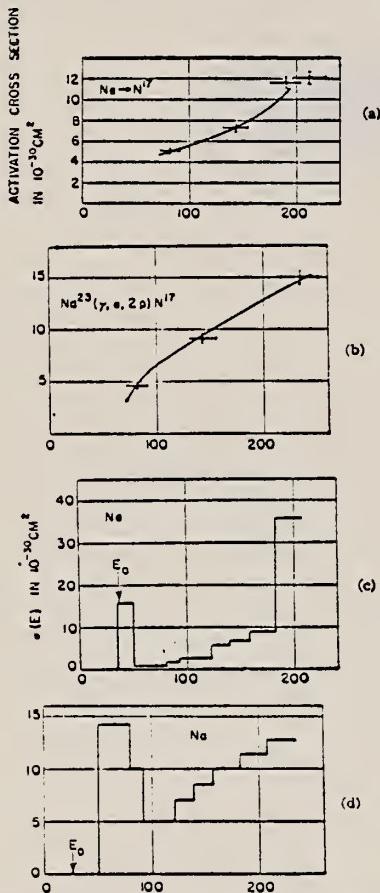


FIG. 4. Experimental N<sup>17</sup> activation points for neon and sodium are plotted in the upper graphs. The lower graphs are the photon cross sections, which were calculated as indicated in the text. The activation cross sections indicated by the solid lines are reconstructions from the photon cross sections shown. The photon cross sections for energies below 80 Mev were chosen arbitrarily.

Elem. Sym.	A	Z
Ne		10

Method

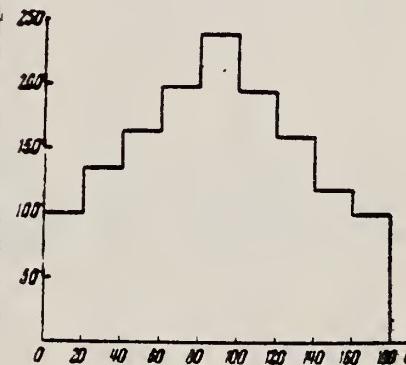
Cloud chamber at 1.4 atm; 80 MeV synchrotron

Ref. No.

57 Ko 1

EGF

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
Ne ( $\gamma, p$ )	Bremss					For $E_p$ (1-15 MeV), $\frac{d\sigma}{dr} = a+b \sin^2 \theta$ , $b/a \approx 2.5$
Ne( $\gamma, pn$ )	80					
Ne( $\gamma, 2p$ )						$\int \sigma (\gamma, p) = 0.16 \pm 0.08$ MeV-b based on
Ne( $\gamma, 2\alpha$ )						Gaerttner and Yeater [Phys. Rev. 83, 146 (1951)].
Ne( $\gamma, \alpha p$ )						
Ne( $\gamma, 5\alpha$ )						

 $(\gamma, p)$ 

The number of observed cases for the separate types of reactions is as follows:

Type of disintegration: ( $\gamma p$ ) ( $\gamma pn$ ) ( $\gamma 2p$ ) ( $\gamma 2\alpha$ ) ( $\gamma \alpha p$ ) ( $\gamma 5\alpha$ )  
 Number of cases: 352 137 64 21 143 2

## **Method**

## Magnetic analysis of proton spectrum produced by electron bombardment

Ref. No

10

62Do1

BG

TABLE VI. Summary of the properties of the major Ne peaks.

Proton energy of peak (MeV)	Photon energy of peak (MeV)	Peak height at 76° (mb/sr)	Photon width at half- height (MeV)	$\int \sigma(\gamma, p) dE_\gamma$ under resonance curve (MeV-mb)	$\% \int_{10}^{37} \sigma(\gamma, p) dE_\gamma$
4.58	17.70	1.45	0.50	11.4	19.0
5.80	18.87	1.11	0.58	11.1	16.7
6.65	19.87	0.90	0.54	7.6	12.7
7.73	21.02	0.77	0.49	6.1	10.3
				Total 36.2	100

TABLE V. Summary of the excitation characteristics of the Na protons

Proton energy (MeV)	Ground state transition energy (MeV)	Experimental threshold (MeV)	Electron energy at which a deviation from an $E1$ isochromat			Energy of ex- cited state (MeV)
			(MeV)	Branching ratio (%)		
4.56	17.68	17.7 ± 0.3	21.8 ± 0.5	17 ± 8	...	4.1 ± 0.5
5.20	18.35	19.4 ± 0.6	21.8 ± 0.7; 27.8 ± 1.2	25 ± 3; 39 ± 10	...	3.5 ± 0.7; 9.5 ± 1.2
5.57	18.74	19.5 ± 0.7	...	...	...	...
5.81	18.99	19.6 ± 0.6	...	...	...	...
6.74	19.97	20.0 ± 0.4	...	...	...	...
7.22	20.47	20.4 ± 0.4	...	...	...	...
7.77	21.00	21.4 ± 0.5	29.8 ± 1	26 ± 10	...	8.8 ± 1
8.30	21.61	21.9 ± 0.5	26.0 ± 1	29 ± 10	...	4.4 ± 1
8.72	22.05	22.3 ± 0.5	26.3 ± 1	29 ± 10	...	4.5 ± 1
9.20	22.56	23.0 ± 0.6	28.2 ± 1.5	29 ± 10	...	5.2 ± 1.5
9.49	22.86	23.0 ± 0.5	27.6 ± 1.5*	29 ± 10	...	4.7 ± 1.5*
9.86	23.25	23.6 ± 0.6	...	...	...	...

**• Slight evidence**

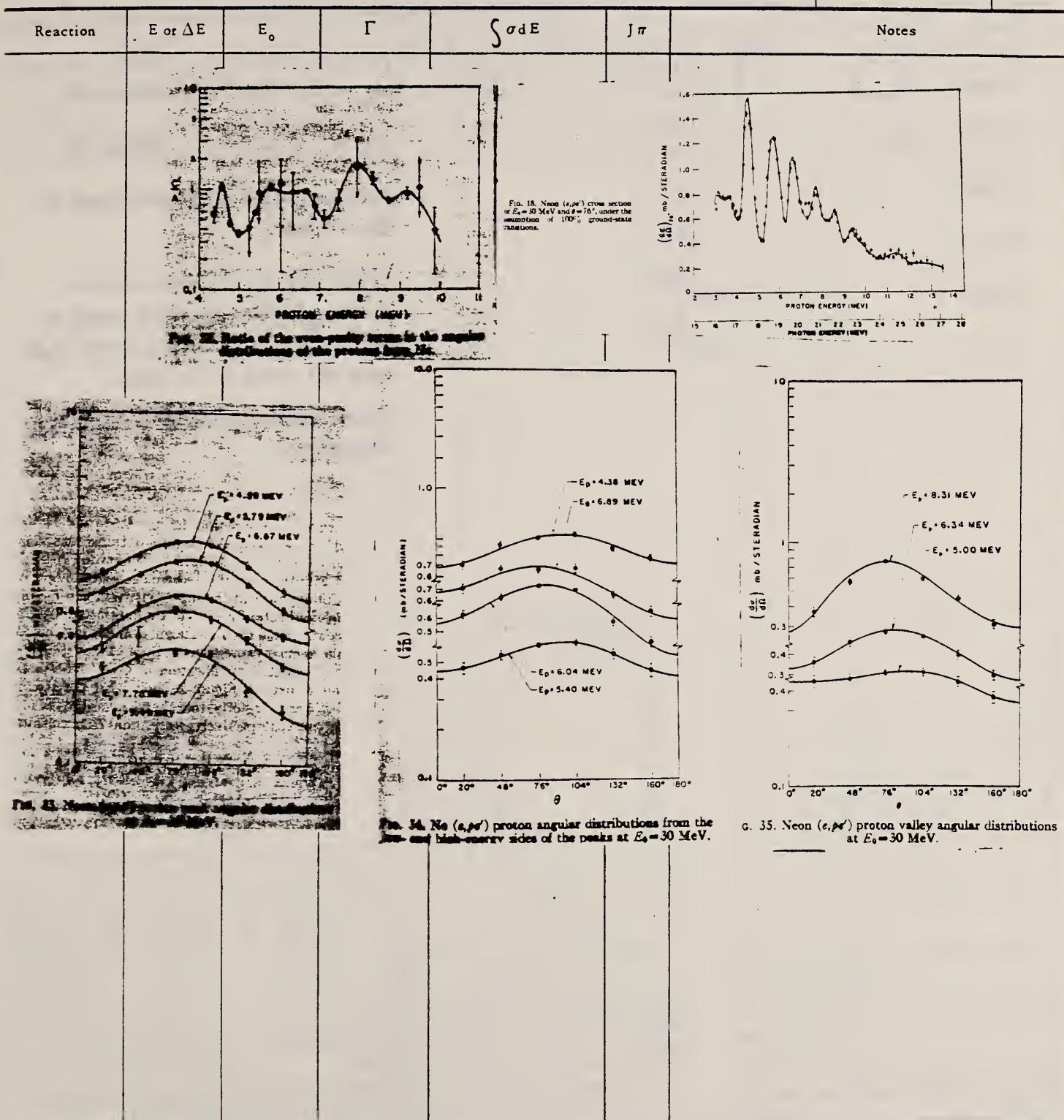
(See page 2 for figures)

Elem. Sym.	A	Z
Ne		10

Method

Magnetic analysis of proton spectrum produced by electron bombardment

Ref. No.  
62 Do 1  
BG



Ref. A. N. Gorbunov, V. A. Dubrovina, V. A. Osipova, V. S. Silanov, P. A. Gorshkov  
Zhur. Neorg. i Zhestk. Tsvet. Met., 42, 747 (1962);  
Russian Phys. JETP 15, 520 (1962).

Elem. Sym.	A	Z
Ne		10
Ref. No.		
625a1		BG

Method

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	Jπ	Notes
( $\gamma, p$ )	$E_{\gamma} = 170$		$165)_{0}^{170}$	M.e.v.-mb		$\sigma_{-1} = \int \sigma(E) E^{-1} dE$ (Table IV)
( $\gamma, n$ )	170		$115)_{0}^{170}$			$\sigma_{-2} = \int \sigma(E) E^{-2} dE$ (Table IV)
( $\gamma, 2n$ )			$66)_{0}^{170}$			Absolute values of yields given in the article.
( $\gamma, 2p$ )			$6)_{0}^{170}$			( $\gamma, n$ ) and ( $\gamma, 2n$ ) could not be distinguished - all were taken to be ( $\gamma, n$ ); similarly ( $\gamma, p$ ) and ( $\gamma, 4$ ) were all taken to be ( $\gamma, p$ ).
( $\gamma, 4n$ )			$38)_{0}^{170}$			Charge distribution parameters were determined.
( $\gamma, 4p$ )			$600)_{0}^{170}$			

Table I									
Reaction	Reaction Threshold, MeV			Reaction	Reaction Threshold, MeV			Reaction	Reaction Threshold, MeV
	N	O	Ne		N	O	Ne		
( $\gamma, n$ )	10.54	15.50	16.79	( $\gamma, 2n$ )	16.06	—	11.82		
( $\gamma, p$ )	7.51	12.11	12.79	( $\gamma, 2pn$ )	19.86	34.56	27.61		
( $\gamma, d$ )	10.26	20.72	20.99	( $\gamma, 2pn$ )	28.44	30.18	23.51		
( $\gamma, z$ )	11.61	7.15	1.67	( $\gamma, 2zn$ )	—	—	30.53		
( $\gamma, pn$ )	12.49	22.04	23.22	( $\gamma, 4z$ )	—	—	14.43		
( $\gamma, 2n$ )	20.05	25.86	20.26	( $\gamma, 32pn$ )	19.77	—	—		
( $\gamma, 2p$ )	18.20	23.19	16.78	( $\gamma, 4p2n3n$ )	—	42.71	—		
( $\gamma, 4p$ )	25.08	32.32	30.76						

Table IV									
Reaction type	$\sigma_0$ , MeV-mb			$\sigma_{-1}$ , mb			$\sigma_{-2}$ , mb-MeV <sup>-1</sup>		
	He <sup>+</sup>	N <sup>14</sup>	O <sup>16</sup> /Ne	He <sup>+</sup>	N <sup>14</sup>	O <sup>16</sup> /Ne	He <sup>+</sup>	N <sup>14</sup>	O <sup>16</sup> /Ne
( $\gamma, p$ )	38	38	129/165	1.09	2.3	5.3	6.5	0.035	0.14/0.22/0.25
( $\gamma, n$ )	44	31	105/115	1.09	1.3	3.4	3.5	0.031	0.06/0.11/0.10
( $\gamma, pn$ )	12	128	39/66	0.18	5.1	1.3	1.4	0.003	0.18/0.03/0.03
( $\gamma, z$ )	—	9	4/6	—	0.3	0.3	0.8	—	0.01/0.02/0.07
( $\gamma, 2n$ )	—	5	15/38	—	0.1	0.3	1.0	—	0.003/0.005/0.02
Stars:									
3-prong	—	53	71/151	—	1.2	1.4	2	—	0.03/0.03/0.12
4-prong	—	70	27/34	—	1.8	0.5	1.5	—	0.04/0.01/0.05
5-prong	—	14	23/15	—	0.2	0.3	0.2	—	0.002/0.003/0.003
6-prong	—	—	3/10	—	—	0.03	0.1	—	—/0.001/0.001
$\sigma_{-1}^{\text{exp}}$	95 ±	347	438/600	2.40 ± 0.15	12.5	12.8	18.0	0.07 ± 0.005	0.48/0.43/0.60
$\sigma_{\text{theor}}$	60	210	240/300	2.3	12.1	13.1	19.5	0.023	0.18/0.23/0.33
$\sigma_{\text{exp}}/\sigma_{\text{theor}}$	1.6	1.65	1.8/2.0	1.04	1.03	0.98	0.91	3.0	2.6/1.8/1.8

Table I

Reaction	Reaction Threshold, MeV			Reaction	Reaction Threshold, MeV		
	N	O	Ne		N	O	Ne
( $\gamma$ , n)	10.54	15.60	16.79	( $\gamma$ , 2n)	16.06	—	11.82
( $\gamma$ , p)	7.51	12.11	12.79	( $\gamma$ , p $\alpha$ )	19.86	34.56	27.61
( $\gamma$ , d)	10.26	20.72	20.99	( $\gamma$ , 2 $\alpha$ )	23.44	30.38	23.81
( $\gamma$ , t)	11.81	7.15	1.67	( $\gamma$ , 3n)	—	—	30.53
( $\gamma$ , 2n)	12.49	22.94	23.22	( $\gamma$ , 4n)	—	—	14.43
( $\gamma$ , 3n)	20.05	25.86	20.26	( $\gamma$ , 3 $\alpha$ )	19.77	—	—
( $\gamma$ , 2 $\alpha$ )	18.20	23.19	16.78	( $\gamma$ , 4p $\alpha$ )	—	42.71	—
( $\gamma$ , 4p)	25.08	32.32	30.76				

Table IV

Reaction type	$\sigma_0, \text{mb}$				$\sigma_{\text{tot}}, \text{mb}$				$\sigma_{\text{tot}}, \text{mb-MeV}^{-1}$			
	He <sup>+</sup>	NH <sub>3</sub>	O <sub>2</sub>	Ne	He <sup>+</sup>	NH <sub>3</sub>	O <sub>2</sub>	Ne	He <sup>+</sup>	NH <sub>3</sub>	O <sub>2</sub>	Ne
(T, p)	38	38	129/165	—	1.09	2.5	5.3	6.5	0.035	0.14	0.22	0.25
(T, n)	31	105/115	—	—	1.09	1.5	3.4	3.5	0.031	0.05	0.11	0.10
(T, pn)	12	128	59/66	0.18	—	5.1	1.3	4.1	0.003	0.18	0.03	0.03
(T, 2j)	—	9	4/6	—	—	0.3	0.3	0.6	—	0.01	0.02	0.07
(T, 3n)	—	5	15/38	—	—	0.1	0.3	1.0	—	0.003	0.005	0.02
Sigma	—	—	—	—	—	—	—	—	—	—	—	—
3-prong	—	53	71/151	—	—	1.2	1.4	4.2	—	0.03	0.03	0.12
4-prong	—	70	27/34	—	—	1.6	0.5	0.5	—	0.04	0.01	0.01
5-prong	—	14	23/15	—	—	0.2	0.3	0.2	—	0.002	0.0030	0.003
6-prong	—	—	5/10	—	—	0.03	0.1	—	—	0.001	0.001	—
$\sigma_{\text{exp}}$	95	347	438/600	2.40 $\pm$ 0.15	12.5	12.8	18.0	0.07 $\pm$ 0.005	0.46	0.43	0.60	—
$\sigma_{\text{theor}}$	60	210	240/300	2.3	—	12.1	13.1	19.5	0.023	0.18	0.23	0.33
$\sigma_{\text{exp}}/\sigma_{\text{theor}}$	1.6	1.85	1.82	0	1.04	1.03	0.98	0.9	3.0	2.6	1.8	1.8

$\sigma_{exp}$ —experimental value of the integrated absorption cross sections  $\sigma_0$ ,  $\sigma_1$  and  $\sigma_{exp}$ .  
 $\sigma_{theor}$ —the theoretical values  $\sigma_{theor}$  have been calculated by means of the expressions:  
 $\sigma_0 = 60(NZ/A)^{1/2} \text{ mb}$ ;  $\sigma_1 = 0.36 A^{1/3} \text{ mb}$ ;  $\sigma_{exp} = 2.25 A^{1/4} \text{ mb}^{-1} \text{ keV}^{-1}$ .

METHOD Betatron; proton spectrum; cross section; nuclear emulsions

REF. NO.

62 Su 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XP	SPC	16-23	C	23	EMU-D	2-13	90
				(23.5)			

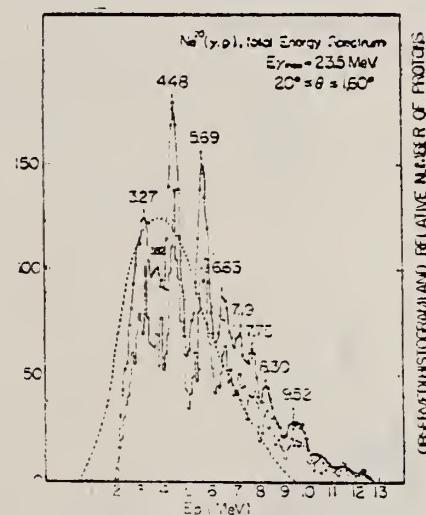


Fig. 1. Energy distributions of photoprotons from  $\text{Ne}^{20}$ . This histogram is for the total number of detected protons. The solid line is a smoothed curve by Valoshek's method. The broken line is a calculated curve using the statistical theory with Weisskopf's level density

$$\nu = C \exp [2\sqrt{0.245 E}] \text{ MeV}^{-1}$$

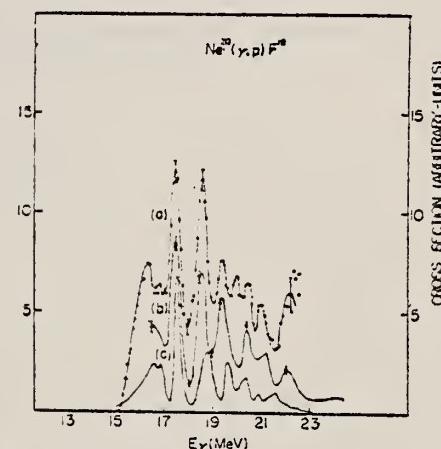


Fig. 2. Comparison of experiments for  $\text{Ne}^{20}(\gamma, p)\text{F}^{19}$ .  $\text{Ne}^{20}(e, e'p)$  and  $\text{F}^{19}(p, \gamma_0)$ .

Curve (a)—present work, the observed energy spectrum is divided by number of photons, assuming all proton transitions are to the ground state of  $\text{F}^{19}$ .

Curve (b)— $\text{Ne}^{20}(e, e'p)$  by Dodge and Barber.  
Curve (c)— $\text{Ne}^{20}(\gamma_0, p)$  reduced from  $\text{F}^{19}(p, \gamma_0 + \gamma_1)$  using the detailed balance by Tanner and Thomas.

METHOD

Betatron; proton spectrum, cross section; CsI spectrometer

REF. NO.

63 Fi 4

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XP	SPC	15-29	C	31	SCI-D	2-15	90

Maxima:  $E_p = 3.5$  MeV  
 = 3.95 MeV  
 = 4.65 MeV  
 = 5.8 MeV  
 = 7.1 MeV  
 = 7.7 MeV  
 = 8.5 MeV  
 = 9.3 MeV  
 = 11.25 MeV  
 = 12.4 MeV

796

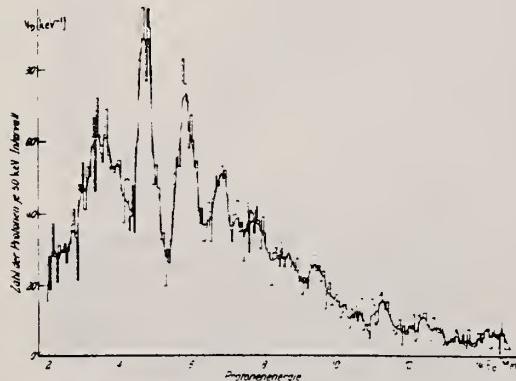


Fig. 1. Energieverteilung der Photoprotonen aus Neon. Das Histogramm stellt die auf Energiedurchgangskoeffizienten komponierten Medewerte dar; die unterste Kurve wurde nach einem Mittelungsverfahren gewonnen. Nähere Erläuterungen im Text.

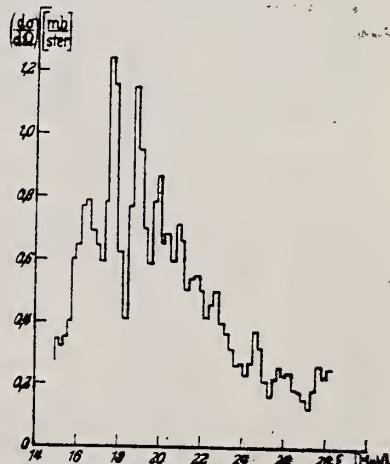


Fig. 3. Differentialer Wirkungsquerschnitt für Photoprotoneemission aus Neon unter 90° zum  $\gamma$ -Strahl unter der Annahme, daß nur Grundzustandsübergänge aus  $Ne^{40}$  in  $Ne^{41}$  vorliegen.

METHOD		REF. NO.			
		74 Ve 1	egf		
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE	RANGE	
G, N *	ABX	16- 26	D	16- 26	BF3-I
G, 2N **	ABX	18- 26	D	18- 26	BF3-I

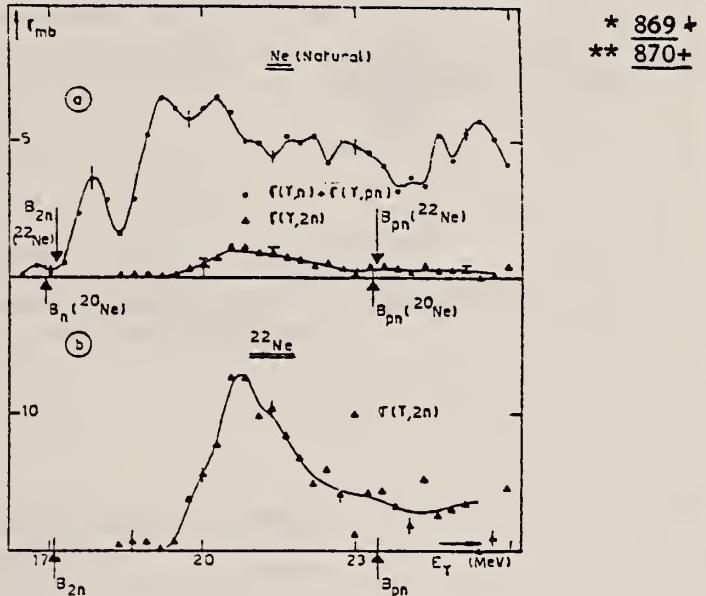


Fig. 4. (a) Photonuclear cross sections  $[\sigma(\gamma, n) + \sigma(\gamma, pn)]$  and  $\sigma(\gamma, 2n)$  for natural Ne. (b) Partial photoneutron cross section  $\sigma(\gamma, 2n)$  of  $^{22}\text{Ne}$ .

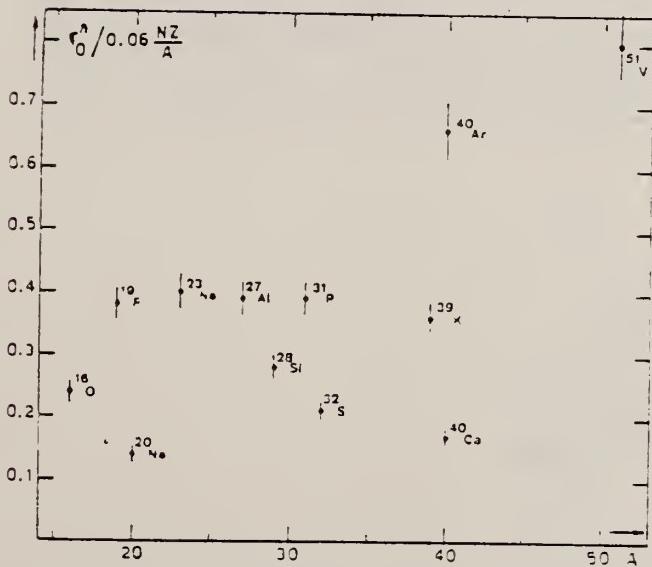


Fig. 22. Ratio of experimental integrated photoneutron cross section  $\sigma_0^n$  over the Thomas, Reiche and Kuhn sum rule  $[0.06 NZ/A]$ . Numerical values and upper integration limits  $E_f$  are taken from table 3. Also  $\Delta\sigma_0^n = \pm 7\%$  for all nuclei.

(over)

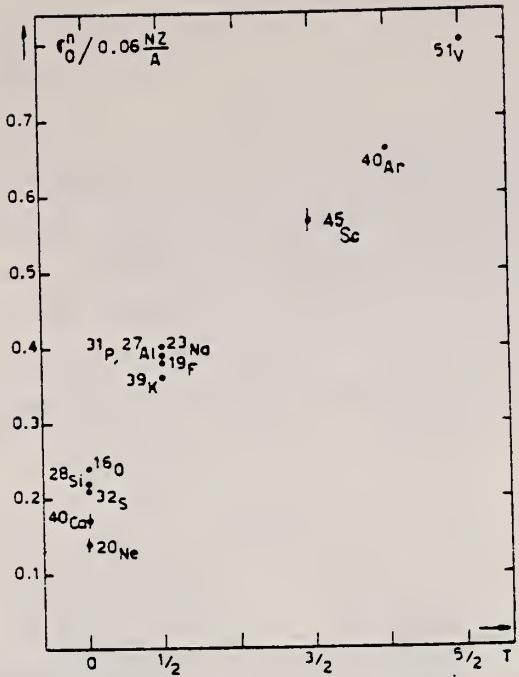


Fig. 24. The  $[\sigma_0^n / (0.06 NZ/A)]$  ratio as a function of isospin  $T$ . Possible overall errors of  $\pm 7\%$  are to be applied to all nuclei shown.

TABLE 3  
Experimental integrated photoneutron cross sections  $\sigma_0^n = \int_0^{E_M} \sigma_{Tn}(E) dE$  compared with the classical sum rule  $[0.06 NZ/A]$  of Thomas, Reich and Kuhn

Nucleus	$T = 0$					$T = \frac{1}{2}$					$T = \frac{3}{2}$	$T = 2$	$T = \frac{5}{2}$
	$^{16}\text{O}$	$^{20}\text{Ne}$	$^{23}\text{Si}$	$^{32}\text{S}$	$^{40}\text{Ca}$	$^{19}\text{F}$	$^{23}\text{Na}$	$^{27}\text{Al}$	$^{31}\text{P}$	$^{39}\text{K}$	$^{45}\text{Sc}$	$^{40}\text{Ar}$	$^{51}\text{V}$
$\sigma_0^n$ (MeV · mb)	58 $\pm 4$	42 $\pm 3$	94 $\pm 7$	98 $\pm 7$	100 $\pm 7$	108 $\pm 7$	137 $\pm 9$	158 $\pm 10$	182 $\pm 12$	210 $\pm 14$	383 $\pm 25$	393 $\pm 28$	602 $\pm 42$
$\sigma_0^n / (0.06 NZ/A)$	0.24	0.14	0.22	0.21	0.17	0.38	0.40	0.39	0.39	0.36	0.57	0.66	0.8
$E_M$ (MeV)	30	26.7	30	30	29.5	29	30	30	29	30	28.1	26.7	28

METHOD	REF. NO.				
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
G,N	ABX	17- 31	C 19- 32	TOF-D	90

NORMALIZED TO D(G,N)

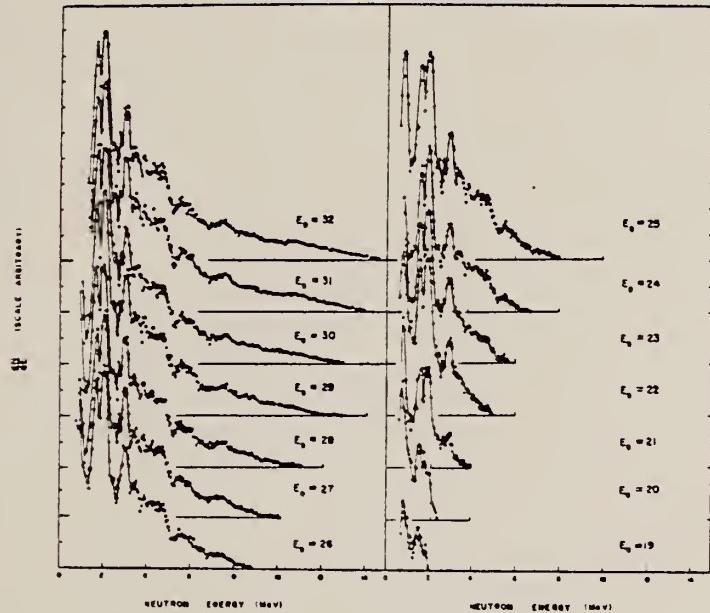


FIG. 3. Photoneutron spectra from  $^{20}\text{Ne}$ .

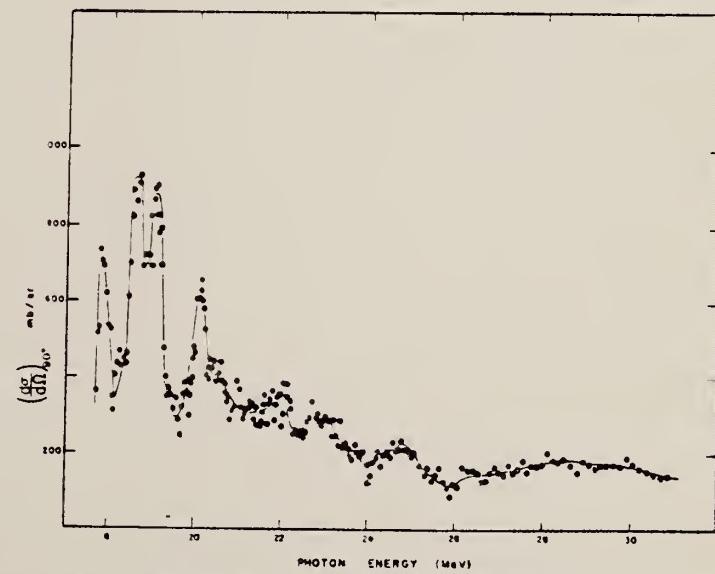


FIG. 5. The cross section for the reaction  $^{20}\text{Ne}(\gamma, n_0 + n_1 + n_2)^{19}\text{N}$ .



$N_t$   
A=20

$N_E$   
A=20

$N_E$   
A=20



Elem. Sym.	A	Z
Ne	20	10

Method 500 keV Cockcroft-Walton cascade generator; photodisintegration;  
 $\text{Li}^7(p,\gamma)$  reaction.

Ref. No.  
59 Ha 1

EH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes	
						Cross Section	State
$\text{Ne}^{20}(\gamma,\alpha)$	17.63					0.05 mb	ground state $\text{O}^{16}$
	14.8					0.67 mb	6.06 + 6.19
$\text{Ne}^{20}(\gamma,2\alpha)$	17.6					1.80 mb	6.91 + 7.12
	14.8					0.086 mb	ground state
$\text{Ne}^{20}(\gamma,\alpha p)$						$\sim 1.0$ mb	6.06 + 6.14
$\text{Ne}^{20}(\gamma,p)$	17.6					21 mb	ground state and low levels at 0.100, 0.197 MeV
	14.8					$\sim 5$ mb	1.35 + 1.57

METHOD					REF. NO.		
Tandem van de Graaff; inverse; NaI spectrometer					60 Br 1	NVB	
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P,G	RLY	17-23 (16.9-22.9)	D	4-11	NAI-D		45N

Peaks: 18.1 MeV

873+

19.4 MeV

20.45 MeV      All have  
 $\Gamma \approx 350$  keV

21.2 MeV

22.2 MeV

YIELDS IN THE  $F^*(\alpha, \alpha')$  AND  $F^*(\alpha, \gamma)$  REACTIONS

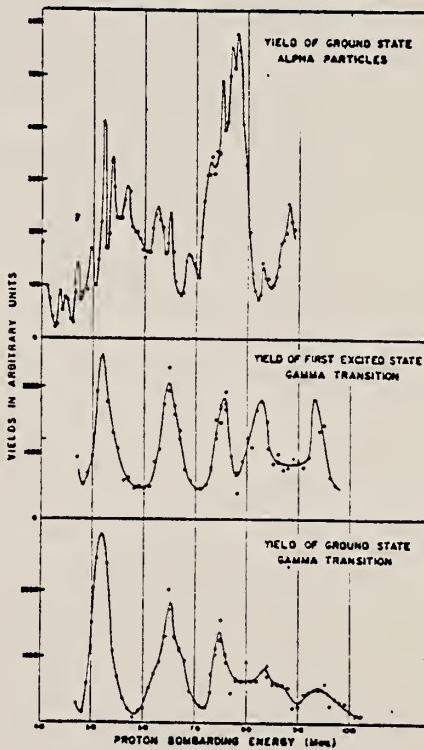


Fig. 1:

REF.

J. M. Reid and B. Lalovic  
 Proc. Phys. Soc. (London) 76, 65 (1960)

ELEM. SYM.	A	Z
Ne	20	10

## METHOD

REF. NO.

60 Re 2

EGF

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,XP	RLY	100-240	C	240	CCH		

185 events ( $\gamma, p$ ) ( $\gamma, pn$ ). Recorded only events where proton with  $20 \leq E \leq 120$  MeV was emitted.

ELEM. SYM.	A	Z
Ne	20	10

## METHOD

Doppler-Shift Attenuation Method

REF. NO. 61 C1 1 JDM

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	1-3	D	1-3	NAI-D	1-3	0

TABLE I

Lifetimes obtained for the first three excited states in  $\text{Ne}^{20}$  using the Doppler shift attenuation technique.  $\alpha$  is the characteristic slowing down time for the target backings listed and  $|M|^2$  is the ratio of the measured gamma-ray transition probability to the Weiskopf value.

Level (MeV)	1.63	4.25	4.97
$E_\gamma$ (MeV)	1.63	2.62	3.34
Slowing materials	Mg, Al	Al, Cu	Mg, Al
$\alpha$ ( $10^{-13}$ sec)	8.9, 5.9	5.9, 2.9	8.9, 5.9
$\tau_{\text{exp.}}$ ( $10^{-10}$ sec)	$5.6 \pm 2.8$	$0.76 \pm 0.72$	$19 \pm 35$
Assumed multi-polarity	$E2$	$E2$	$E1, M2$
$ M ^2$	38	26	$4.4 \times 10^{-4}, 1.6 \times 10^{-3}, 1.6 \times 10^{-8}, 3.3 \times 10^{-8}$

Elem. Sym.	A	Z
Ne	20	10

Method

Linen (Standard Monk II) - counter telescope

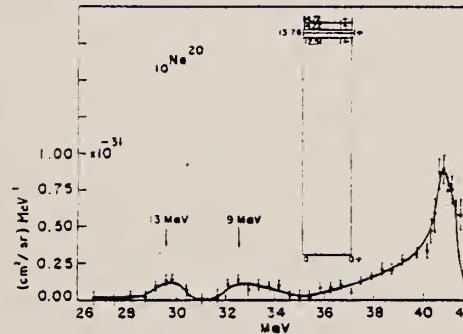
Ref. No.

6301

25

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
(e,e')	41.5		eV			Inelastic electron scattering cross section at $180^\circ$ ( $\text{cm}^2/\text{sr}$ $\times 10^{-32}$ )
		$\sim 9$	7.1	0.9		$3.0 \pm 20\%$
		$\sim 13$	16.6	1.0		$2.0 \pm 20\%$

The rad. widths correspond to transitions from the  $0^+$  state to  $1^+$  excited states.

fig. 10. Spectrum of 41.5 MeV electrons scattered from a neon gas target at  $180^\circ$ .

METHOD					REF. NO.		
$\text{Al}^{27}(\text{p},\gamma_0)\text{Si}^{28}$ ; tandem					64 Al 3	JOC	
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P,G	N $\bar{\chi}$ X	17 - 22	D	4 - 9	NAI-D		DST

Table I. Summary of experimental results on the  $(p, \gamma)$  giant resonance (references 9-11). The angular distributions that are quoted generally characterize the data to within 15% throughout the giant-resonance region.

Nucleus	Type of observation	Energy interval and range	Result
$\text{C}^{12}$	90° yield curve	50-keV steps 4.0-14 MeV	Broad ( $\Gamma \approx 1$ MeV) overlapping levels; no correlation between $\gamma_0$ and $\gamma_1$ .
	Angular distribution <sup>a</sup>	50-keV steps 4.0-14 MeV	$W(\theta)_{\gamma_0} = 1 + 0.15P_1 - 0.6P_2$ $W(\theta)_{\gamma_1} = 1 + 0.15P_1$
$\text{Ne}^{20}$	90° yield curve	30-keV steps 4.3-9.1 MeV	Broad ( $\Gamma \approx 400$ keV) levels usually well isolated, $\gamma_0$ and $\gamma_1$ well correlated.
	Angular distribution	100-keV steps 4.0-10.5 MeV	$W(\theta)_{\gamma_0} = 1 + 0.05P_1 - 0.7P_2$ $W(\theta)_{\gamma_1} = 1 + 0.05P_1 + 0.2P_2$
$\text{Si}^{28}$	90° yield curve	15-keV steps 4.0-12.5 MeV	Narrow ( $\Gamma \approx 50$ keV) Ericson fluctuations, superimposed on intermediate structure; no correlation between $\gamma_0$ and $\gamma_1$ .
	Angular distribution	15-keV steps 4.0-4.32 MeV 6.0-6.62 MeV 8.0-8.54 MeV 10.0-10.28 MeV 11.54-11.58 MeV	$W(\theta)_{\gamma_0} = 1 + 0.07P_1$ $W(\theta)_{\gamma_1} = 1 + 0.1P_1 - 0.45P_2 - 0.1P_3$

<sup>a</sup>The coefficients of  $P_1$  are average values. They actually increase by about 0.03/MeV over the giant resonance.

METHOD $F^{19}(p, \gamma)Ne^{20}$					REF. NO.		
					64 Ta 1	JOC	
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P,G	ABX	17-24	D	4-11	NAI-D		90

At  $E_p = 5.25$  MeV  $\frac{d\sigma\gamma_0}{dr} \Big|_{90} = 350 \pm 110 \text{ mb/4msr}$

From detailed balance:

$$\int_{16.4}^{20.5} \sigma(\gamma, p_0) dE\gamma = 28 \pm 9 \text{ MeV - mb}$$

Comparison with several other  $(p, \gamma)$  results

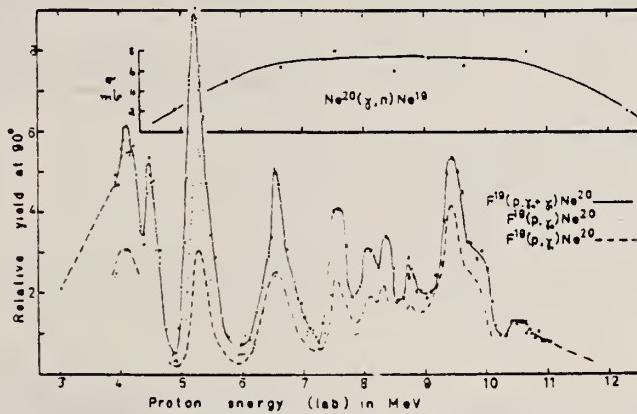


Fig. 4. The excitation function at 90° of  $F^{19}(p, \gamma_1 + \gamma_0)Ne^{20}$ . The data shown in table 2 were used to sketch in the curves for  $\gamma_0$  and  $\gamma_1$  separately. The  $Ne^{20}(\gamma, n)Ne^{19}$  data from ref. <sup>8</sup>) are shown, using an energy scale so that excitation energies in  $Ne^{20}$  correspond.

REF.

A.W. Parker, R.R. Whitehead, and G.G. Shute  
 Aust. J. Phys. 19, 147 (1966)

ELEM. SYM.	A	Z
Ne	20	10

## METHOD

Cyclotron

REF. NO.

66 Pa 3

JDM

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P, G	NOX	17.8	D	5.2	SCI-D		DST
							.

$$W(\theta) \sim 1 + a_1 P_1 + a_2 P_2$$

TABLE I  
 ANGULAR DISTRIBUTIONS CORRECTED FOR SOLID-ANGLE EFFECTS, AND CROSS-SECTION RATIOS

$E_p$ (MeV)	$\gamma$	$a_1$	$a_2$	Cross-section Ratio $R$
5.20	$\gamma_0$	$+0.18 \pm 0.03$	$-0.75 \pm 0.05$	$1.53 \pm 0.04$
	$\gamma_1$	$+0.05 \pm 0.01$	$+0.22 \pm 0.02$	
5.40	$\gamma_0$	$+0.10 \pm 0.03$	$-0.63 \pm 0.03$	$0.62 \pm 0.03$
	$\gamma_1$	$+0.11 \pm 0.04$	$+0.33 \pm 0.04$	

METHOD

Proton capture

[Page 1 of 2]

REF. NO.

67 Se 1

EGF

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P,G	ABX	16-25	D	3-13	NAI-D		DST

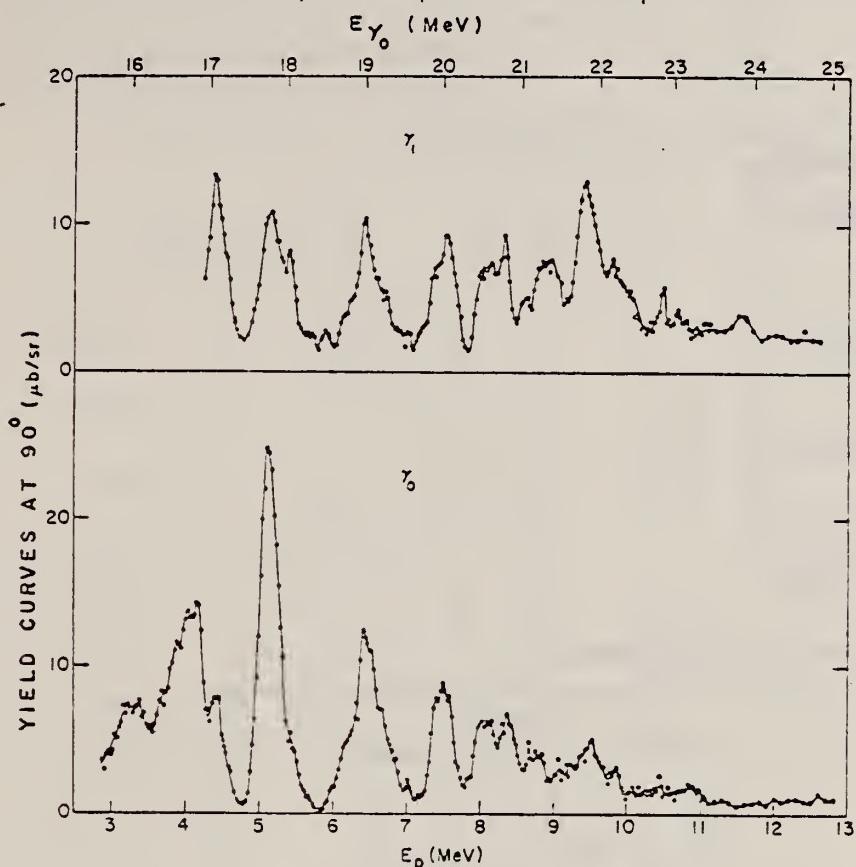
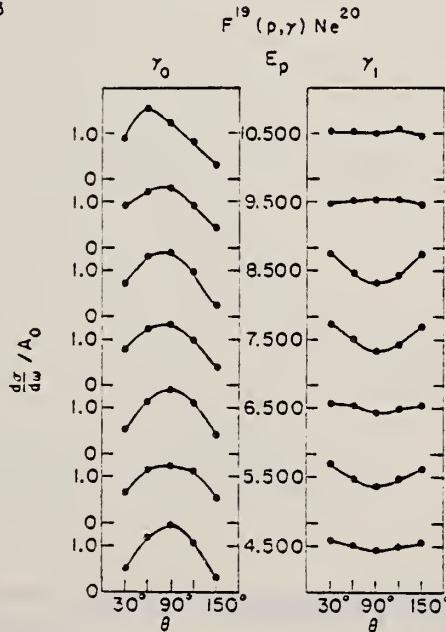


Fig. 5. Yield curves at 90° for  $^{19}\text{F}(\text{p}, \gamma_0)^{20}\text{Ne}$  and  $^{19}\text{F}(\text{p}, \gamma_1)^{20}\text{Ne}$ .



METHOD

Proton capture

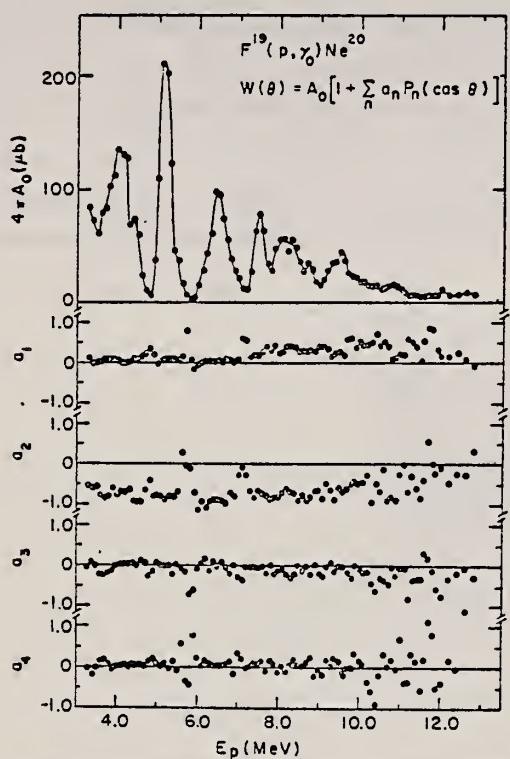


Fig. 9. Coefficients obtained in fitting series of Legendre polynomials to the angular distributions for  $^{19}\text{F}(p, \gamma_0)^{20}\text{Ne}$ .

[Page 2 of 2]

67 Se 1

EGF

DETECTOR		ANGLE
TYPE	RANGE	

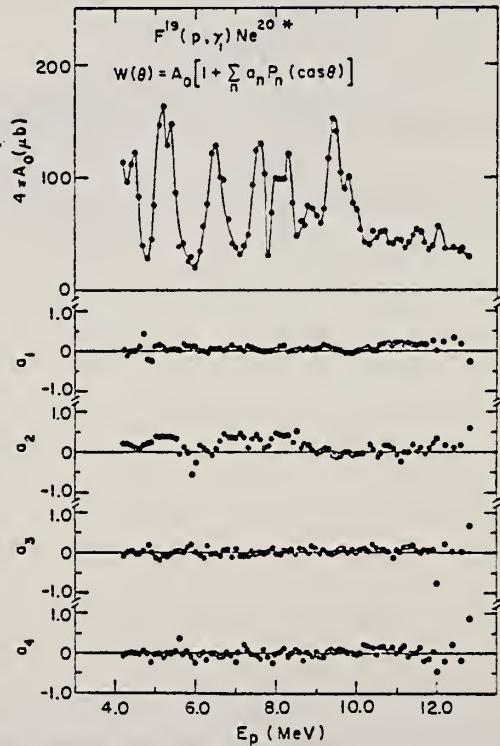


Fig. 10. Coefficients obtained in fitting series of Legendre polynomials to the angular distributions for  $^{19}\text{F}(p, \gamma_1)^{20}\text{Ne}$ .

METHOD						REF. NO.	
						69 Ho 1	egf
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XP	ABY	THR- 33	C	24-33	SCI-D	3-14	90

195

Tabelle 1. Daten zu den einzelnen Reaktionen. Die Werte für den integrierten Wirkungsquerschnitt wurden unter der Annahme ausschließlicher Grundzustandsübergänge berechnet. Für  $^{23}\text{Na}$  und  $^{39}\text{K}$  als Ausnahme s. Text

Target	Anreicherungsgrad %	$(\gamma, \rho)$ -Schwelle MeV	Druck oder Dicke	Endenergie MeV	Zahl gemess. Protonen	Ausbeute $\mu\text{b}/\text{MeV sr}$	$\int \sigma(E) dE$ Figur	
							MeVmb	Figur
$^{18}\text{O}$	99	16,0	230 Torr	32,5	36074	$58 \pm 7$	$38 \pm 6$	1, 2
$^{20}\text{Ne}$	90,9	12,8	450 Torr	28,0	3175	$7,4 \pm 1$	—	—
$^{21}\text{Ne}$	99,9	15,3	610 Torr	32,5	6293	$14,9 \pm 2$	$61 \pm 11$	5, 6
				24,0	1960	$2,3 \pm 0,4$	—	4, 5
				28,0	4790	$3,6 \pm 0,6$	—	4, 5
$^{23}\text{Na}$	100	8,8	65 $\mu$	32,5	5210	$6,7 \pm 0,9$	$45 \pm 8$	4, 5
				24,0	14182	$6,3 \pm 1,0$	—	7
				32,5	11152	$12,8 \pm 2,0$	$117 \pm 30$	7
$^{36}\text{Ar}$	99	8,5	250 Torr	32,5	45173	$57 \pm 6$	$270 \pm 40$	8, 10
$^{40}\text{Ar}$	99,6	12,5	230 Torr	32,5	29559	$14,2 \pm 1,5$	$104 \pm 15$	9, 11
$^{39}\text{K}$	93,1	6,4	80 $\mu$	32,5	24230	$17,4 \pm 2,8$	—	12
				32,5	24941	$41,9 \pm 6,7$	$405 \pm 100$	12
$^{84}\text{Kr}$	99	10,7	170 Torr	32,5	35515	$12,7 \pm 2,0$	$80 \pm 20$	14
Kr	natürl.	10	170 Torr	32,5	13570	$12,5 \pm 2,0$	$75 \pm 20$	13
Ne	natürl.	9	150 Torr	32,5	7553	$7,6 \pm 0,9$	$40 \pm 7$	15

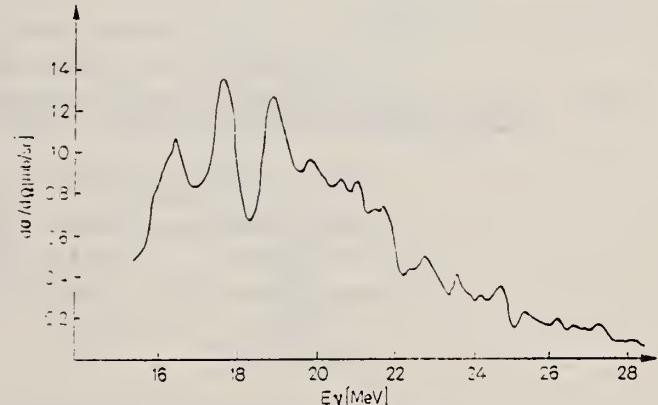


Fig. 5. Der  $(\gamma, \rho)$ -Wirkungsquerschnitt für  $^{20}\text{Ne}$

ELEM. SYM.	A	Z
Ne	20	10

METHOD				REF. NO.	
				71 Be 1	hmg

11.23, 11.58 MEV

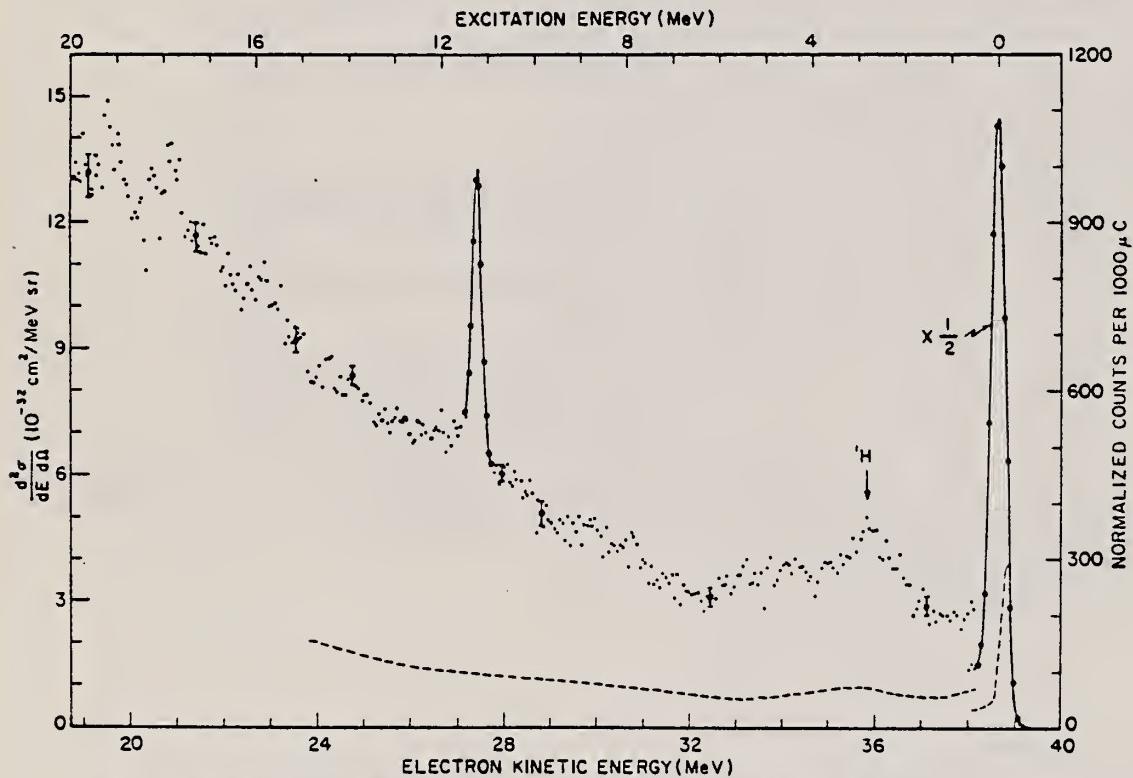


FIG. 2. Spectrum obtained by 180° scattering of 39-MeV electrons from  $^{20}\text{Ne}$ . The dashed line shows the spectrum obtained with an evacuated chamber, in terms of counts per  $1000 \mu\text{C}$  only.

TABLE I. Values of differential cross sections, spin and parity, transition radius, and radiation width for levels excited in  $^{20}\text{Ne}$ , with DWBA corrections.

Level energy (MeV)	$(d\sigma/d\Omega)_{50} \times 10^{-34} \text{ cm}^2/\text{sr}$	$(d\sigma/d\Omega)_{30} \times 10^{-34} \text{ cm}^2/\text{sr}$	$J^\pi$	$R$ (fm)	$\Gamma_0$ (eV)
11.235 <sup>a</sup>	$145 \pm 5$	$219 \pm 10$	$1^+$	$2.53 \pm 0.15$	$11.2^{+2.1}_{-1.8}$
$11.58 \pm 0.03$	$16 \pm 4$	$13 \pm 4$	$1^+$ $2^+$ $2^-$	$<1.8^b$ $<2.7^b$ $4.1^{+1.0}_{-1.6}$	$0.65 \pm 0.18^b$ $0.40 \pm 0.13^b$ $0.016 \pm 0.009$

<sup>a</sup>See Refs. 14 and 15.

<sup>b</sup>The value calculated for  $R^2$  is negative, with a positive upper limit. Therefore, the value of  $\Gamma_0$  is calculated assuming that  $R$  is between zero and the maximum value consistent with the data.

<sup>14</sup>R.C. Ritter, J.T. Parson, D.L. Bernard: Phys. Letters 28B, 588 (1969).

<sup>15</sup>B.T. Lawergren, A.T.G. Ferguson, G.C. Morrison, Nucl. Phys. A108, 325 (1968).

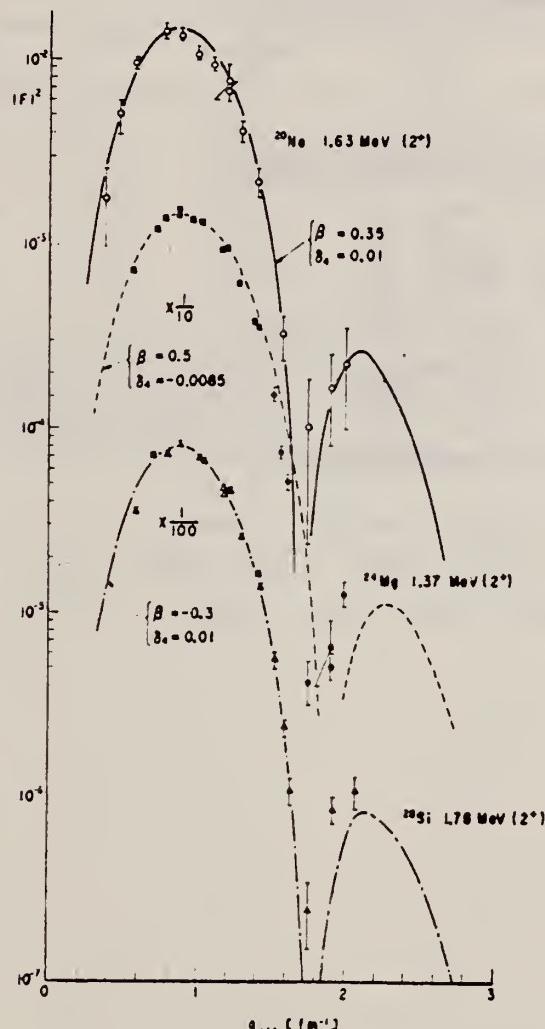
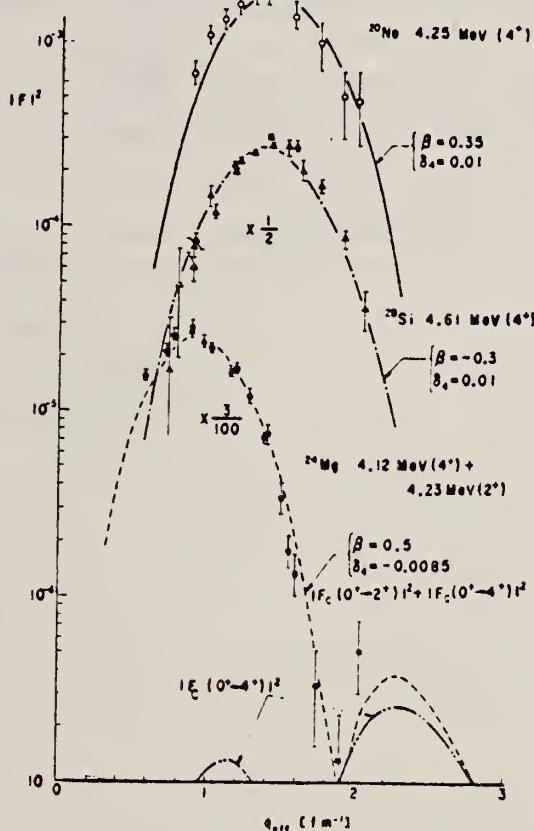


Fig.1. The experimental form factors for the  $2^+$  members of the ground-state rotational bands in  $^{20}\text{Ne}$ ,  $^{24}\text{Mg}$  and  $^{24}\text{Si}$  are shown as a function of the  $q_{\text{eff}}$  [3].



**Fig.2.** The same as for fig. 1 except for the  $4^+$  members. The unresolved data of the 4.12 MeV ( $4^+$ ) and 4.23 MeV ( $2^+$ ) states is presented in the case of  $^{24}\text{Mg}$ .

(over)

- (2) R. de Swiniarski, D. Glashausser, D. L. Hendrie, J. Sherman, A. D. Bacher,  
and E. A. McClatchie, Phys. Rev. Letters 23 (1964) 317.  
(3) D. G. Ravenhall, quoted in: R. Hofstater, Rev. Mod. Phys. 28 (1956) 214.  
(5) H. Rebel, G. W. Schweimer, J. Specht, G. Schatz, R. Lohken, D. Habs,  
G. Hanser and H. Klewe-Nebenius, Phys. Rev. Letters 26 (1971) 1190.

Table 1

The values obtained from the Nilsson orbits which provide the best fit form factors. The signs of the moments were determined by the characteristic of the orbits. The  $\beta_2$  and  $\beta_4$  values of the present study are compared with those of the  $(p, p')$  [2] and  $(\alpha, \alpha')$  [5] reactions.

	$\langle r^2 \rangle^{1/2}$ (fm)	$\langle r^4 \rangle^{1/4}$ (fm)	Q <sub>0</sub> (efm <sup>2</sup> )	II <sub>0</sub> (efm <sup>4</sup> )	$\beta_2$			$\beta_4$		
					present (e, e')	(p, p') ( $\alpha, \alpha'$ )	present (e, e')	(p, p') ( $\alpha, \alpha'$ )	present (e, e')	(p, p') ( $\alpha, \alpha'$ )
<sup>20</sup> Ne	2.91	3.14	+58 ± 3	+249 ± 27	+0.40	+0.47	+0.35 ±0.01	+0.19	+0.28 ±0.05	+0.11 ±0.01
<sup>24</sup> Mg	3.03	3.24	+69 ± 3	+ 48 ± 16	+0.45	+0.47		-0.06	-0.05 ±0.08	
<sup>28</sup> Si	3.14	3.35	-64 ± 3	+205 ± 33	-0.39	-0.37	-0.32 ±0.01	+0.10	+0.25 ±0.08	+0.08 ±0.01

T. K. Alexander, B. Y. Underwood, N. Anyas-Weiss, N.A. Jolley,  
 J. Szucs, S.P. Dolan, M.R. Wormald, and K.W. Allen  
 Nucl. Phys. A197, 1 (1972)

Ne	20	10
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METHOD

REF. NO.

72 A1 4

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
A,G	LFT	7 - 9	D	3 - 5	SCD-D	.	DST

4 LEVELS

TABLE 2  
 Summary of  $\gamma$ -ray decay measurements

$E_i$ (keV)	$J_i'' \rightarrow J_f''$	Branching (%)	$\omega\gamma$ (meV)	$F_\gamma$ (meV)	$ M(E2) ^2$ (W.u.)
7191	$0^+ \rightarrow 2^+$	100	$4.35 \pm 0.75$ *)	$4.35 \pm 0.75$	$0.37 \pm 0.07$
7420	$2^+ \rightarrow 2^+$	$\geq 90.6 \pm 1.4$	$146 \pm 19$ *)	$29 \pm 4$	$1.65 \pm 0.27$ *)
	$2^+ \rightarrow 0^+$	$\leq 9.4 \pm 1.4$ *)	$\leq 15.2 \pm 2.6$ *)	$\leq 3.0 \pm 0.6$	$\leq 0.05 \pm 0.01$
	$2^+ \rightarrow 4^+$	$< 7.6$	$< 11$	$< 2.2$	$< 2.6$
7826	$2^+ \rightarrow 2^+$	$17 \pm 1$	$58 \pm 8$ *)	$11.7 \pm 1.6$	$0.48 \pm 0.07$ *)
	$2^+ \rightarrow 0^+$	$83 \pm 1$	$285 \pm 34$ *)	$57 \pm 7$	$0.73 \pm 0.09$
	$2^+ \rightarrow 4^+$	$< 3$	$< 10$	$< 2$	$< 1.3$
9029	$4^+ \rightarrow 2^+$	100	$3050 \pm 375$ *)	$340 \pm 42$	$5.8 \pm 0.7$
	$4^+ \rightarrow 4^+$	$< 2$	$< 61$	$< 6.8$	$< 1$ *)

\*) Measured relative to  $\omega\gamma(6^+) = 1.36 \pm 0.14$  eV, refs. <sup>22,23</sup>.\*)  $\delta(E2/M1) = -8.36 \pm 1.9$ ,  $|M(M1)|^2 = (1.0 \pm 0.3) \times 10^{-4}$  W.u.\*) Measured relative to  $\omega\gamma(2^+, T = 1) = 22.2 \pm 2.4$  eV, ref. <sup>16</sup>.

\*) Assumed to be pure E2.

\*) Considered an upper limit since off-resonance intensity was not measured.

<sup>16</sup>J. D. Pearson et al., Nucl. Phys. 54 (1964) 434<sup>22</sup>W. T. Diamond et al., Can. J. Phys. 49 (1971) 1589<sup>23</sup>D. W. O. Rogers et al., Can. J. Phys. 49 (1971) 1397

METHOD				REF. NO.	
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
E, E/	FMF	6-8	D TYPE RANGE	MAG-D TYPE RANGE	DST

6.72-7.84 MEV LEVELS

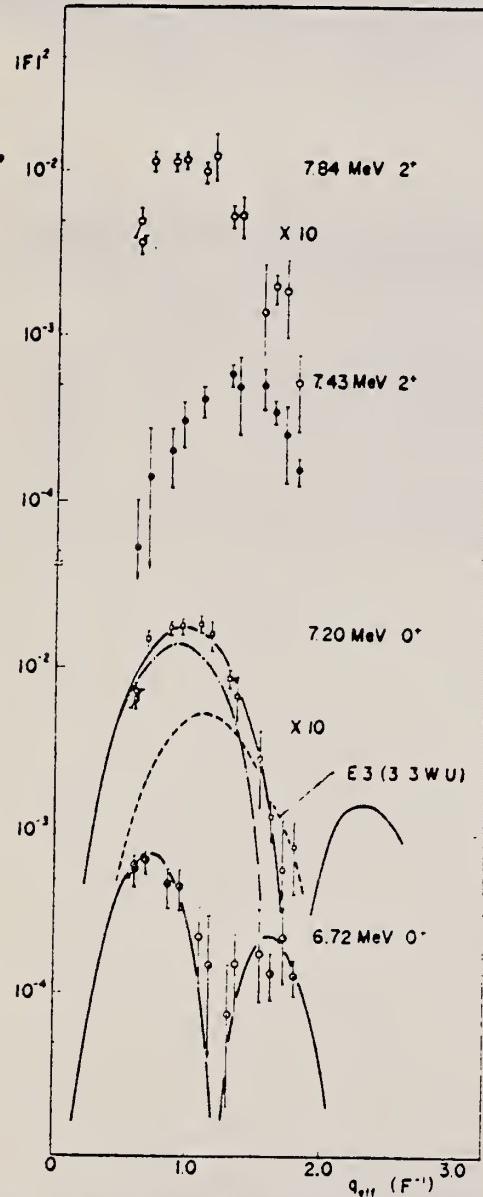


TABLE I. Matrix elements  $M$ , transition radii  $R_{tr}$ , and reduced transition probabilities  $B(E2)$ .

	$E_x$ (MeV)	$J^\pi$	$M$ (F <sup>2</sup> )	$R_{tr}/A^{1/3}$ (F)	$B(E2)/B_{1.p.}$
<sup>20</sup> Ne	6.72	0 <sup>+</sup>	$7.37 \pm 1.97$	$2.11 \pm 0.48$	
<sup>20</sup> Ne	7.20	0 <sup>+</sup>	$6.90 \pm 1.44$	$1.69 \pm 0.52$	
<sup>28</sup> Si	4.98	0 <sup>+</sup>	$6.63 \pm 2.43$	$1.81 \pm 0.51$	
			$6.82 \pm 0.52^*$	$1.86 \pm 0.09^*$	
<sup>20</sup> Ne	7.43	2 <sup>+</sup>			$0.13 \pm 0.03$
<sup>20</sup> Ne	7.84	2 <sup>+</sup>			$0.83 \pm 0.13$

\*Ref. 12.

P. Strehl and T.H. Schucan, Phys. Lett. 27B, 641 (1968).

FIG. 2. Experimental form factors for the 6.72- (0<sup>+</sup>), 7.20- (0<sup>+</sup>), 7.43- (2<sup>+</sup>), and 7.84-MeV (2<sup>+</sup>) states, plotted against  $q_{eff}$ .

METHOD

REF. NO.

73 Si 15

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E.E/	FMF	1- 8	D	77-115	MAG-D		DST

6 LEVELS

TABLE I. Experimental form factors for  $^{20}\text{Ne}$

$E_0$ (MeV)	$\theta$ (deg)	Square of experimental form factor $\times 10^4$ (errors in %)						
		5.63 MeV			7.17 MeV			
		$1.625 \text{ MeV}$	$4.24 \text{ MeV}$	$5.78 \text{ MeV}$	$6.72 \text{ MeV}$	$7.20 \text{ MeV}$	$7.84 \text{ MeV}$	
81.28	60	31.62 (15)						
81.28	75	46.28 (15)						
102.40	60	60.56 (15)		4.956 (15)	2.480 (25)			
102.40	75	93.41 (10)						
77.00	125	86.50 (10)						
81.28	125	113.5 (10)						
77.00	140	115.2 (10)						
102.40	90	103.5 (10)	1.833 (25)	18.64 (15)	3.165 (20)	7.090 (20)	4.340 (20)	
102.40	110	110.0 (10)	3.940 (20)	24.74 (15)	2.730 (20)	11.20 (20)	5.244 (20)	
114.40	110	86.34 (10)						
102.40	140	108.8 (10)		32.00 (15)				
110.50	140	60.33 (20)						

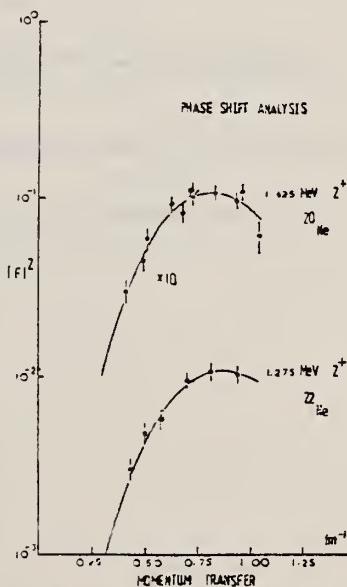


FIG. 6. The result of best fits to the 1.625 MeV,  $2^+$  state in  $^{20}\text{Ne}$  and 1.275 MeV,  $2^+$  state in  $^{22}\text{Ne}$ . Tassie model has been used in a phase shift code for the fits.

REF.

I.I. Chkalov, N.G. Shevchenko, A.Yu. Buki, A.A. Khomich,  
 A.S. Litvinenko, and V.N. Polishchuk  
*Yad. Fiz.* 22, 893 (1975)  
*Sov. J. Nucl. Phys.* 22, 464 (1976)

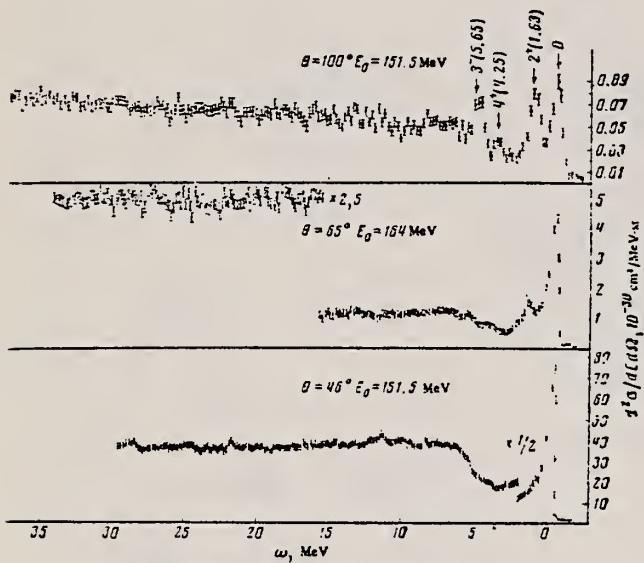
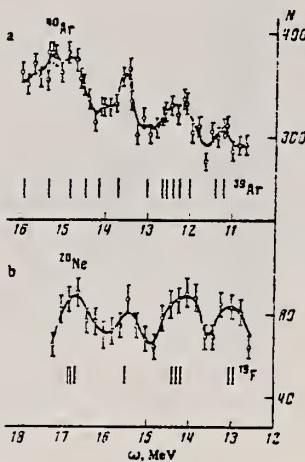
ELEM. SYM.	A	Z
Ne	20	10

METHOD

REF. NO.
75 Ch 4

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,E/	SPC	0- 35	D	151,164	MAG-D		DST

Experimental results are presented of a study of the fine structure of the giant resonance in the nuclei  $^{20}\text{Ne}$  and  $^{40}\text{Ar}$  by the method of inelastic scattering of electrons. A correlation is observed between the energy positions of the maxima of the fine structure of the giant resonance in the nuclei  $^{20}\text{Ne}$  and  $^{40}\text{Ar}$ , on the one hand, and the positions of the discrete levels in the respective nuclei  $^{19}\text{F}$  and  $^{39}\text{Ar}$ , on the other.

FIG. 1. Spectra of electrons scattered by  $^{20}\text{Ne}$ .FIG. 3. Fine structure of the giant resonance in the nuclei  $^{40}\text{Ar}$  (a) and  $^{20}\text{Ne}$  (b) at  $\theta = 100^\circ$  and  $E_0 = 152$ , and the discrete-level schemes of the nuclei  $^{39}\text{Ar}$  and  $^{19}\text{F}$ .

The electrodisintegration cross sections,  $^{16}\text{O}(\text{e}, \alpha_0)^{12}\text{C.e}'$  and  $^{20}\text{Ne}(\text{e}, \alpha_0)^{16}\text{O.e}'$ , have been measured and, by using virtual photon analysis, a comparison with photodisintegration experiments has been made. Satisfactory agreement with earlier  $^{12}\text{C}(\alpha, \gamma_0)^{16}\text{O}$  experiments was found and the  $^{20}\text{Ne}(\text{e}, \alpha_0)^{16}\text{O}$  reaction reveals several pronounced resonances.

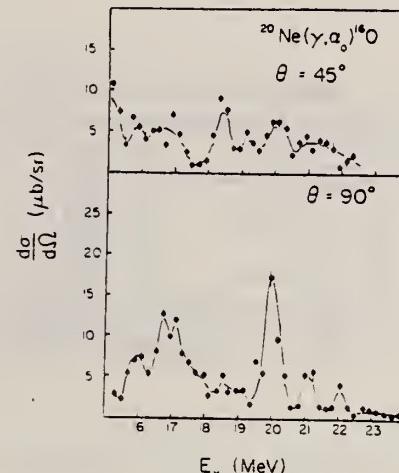


FIG. 2. Comparison of the  $^{20}\text{Ne}(\gamma, \alpha_0)$  cross sections at  $\theta = 45^\circ$  and  $90^\circ$ .

REF.	L.K. Fifield, F. P. Calaprice, C. H. Zimmerman, M. J. Hurst, A. Pakkanen, T. J. M. Symons, F. Watt and K. W. Allen Nucl. Phys. A288, 57 (1977)	ELEM. SYM.	A	Z
		Ne	20	10
METHOD	REF. NO.			.
	77 Fi 6			egf
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR
			TYPE RANGE	TYPE RANGE
A,G	LFT	10	D 6	SCD-D

**Abstract:** The radiative widths for decays of the  $^{20}\text{Ne}$   $T = 1, 2^+$  (10.27 MeV) state were measured by resonance  $\alpha$ -capture in the reaction  $^{16}\text{O}(\alpha, \gamma)^{20}\text{Ne}$ . A special windowless gas-cell target yielded a low-background spectrum enabling six  $\gamma$ -branches to be observed with a Ge(Li) detector. The six branches correspond to decays from the 10.27 MeV level to the following levels:  $2^+(7.83 \text{ MeV})$ ,  $2^+(7.42 \text{ MeV})$ ,  $3^-(5.62 \text{ MeV})$ ,  $2^-(4.97 \text{ MeV})$ ,  $2^+(1.63 \text{ MeV})$  and  $0^+(\text{g.s.})$ . The branching ratios and radiative widths  $\Gamma$ , to these levels are:  $7.83 \text{ MeV}$  [ $(0.22 \pm 0.06)\%$ ,  $0.008 \pm 0.002 \text{ eV}$ ],  $7.42 \text{ MeV}$  [ $(6.9 \pm 0.4)\%$ ,  $0.31 \pm 0.04 \text{ eV}$ ],  $5.62 \text{ MeV}$  [ $(2.1 \pm 0.2)\%$ ,  $0.097 \pm 0.014 \text{ eV}$ ],  $4.97 \text{ MeV}$  [ $(1.3 \pm 0.1)\%$ ,  $0.060 \pm 0.008 \text{ eV}$ ],  $1.63 \text{ MeV}$  [ $(88.9 \pm 0.5)\%$ ,  $4.08 \pm 0.43 \text{ eV}$ ] and  $0.0 \text{ MeV}$  [ $(0.64 \pm 0.14)\%$ ,  $0.029 \pm 0.008 \text{ eV}$ ]. The radiative widths to the  $1.63 \text{ MeV}$  and  $7.42 \text{ MeV}$  levels are used to determine the CVC predictions of the weak magnetism form factors and their effects on certain  $\beta$ -decay observables are evaluated.

10=10.27 MeV

TABLE 2  
Branching ratios and transition energies for the 6.93 MeV resonance

Transition	$E_{\gamma}^{(0)}$ (keV)	Branch (%)
$R \rightarrow 0$	$10266.1 \pm 5.0$	$0.65 \pm 0.14$
$R \rightarrow 1.63$	$8636.3 \pm 3.2$	$88.9 \pm 0.5$
$R \rightarrow 4.97$	$5305.2 \pm 3.8$	$1.3 \pm 0.1$
$R \rightarrow 5.62$	$4649.6 \pm 2.2$	$2.1 \pm 0.2$
$R \rightarrow 7.42$	$2847.9 \pm 1.2$	$6.9 \pm 0.4$
$R \rightarrow 7.83$	$2442.9 \pm 2.6$	$0.22 \pm 0.06$
$4.97 \rightarrow 1.63$	$3332.0 \pm 1.9$	

TABLE 4  
Transition strengths for the 6.93 MeV resonance

Transition	Type	$\omega_{\gamma}$ (eV)	$\Gamma_{\gamma}$ (eV)	$ M ^2$	$ M ^2$ (W.u.)
$R \rightarrow 0.0$	E2	$0.14 \pm 0.04$	$0.029 \pm 0.008$	$0.32 \pm 0.09 e^2 \cdot \text{fm}^4$	$0.10 \pm 0.03$
$R \rightarrow 1.63$	M1	$19.7 \pm 2.1$	$4.08 \pm 0.44$	$0.55 \pm 0.06 \mu_N^2$	$0.31 \pm 0.03$
$R \rightarrow 4.97$	E1	$0.29 \pm 0.04$	$0.060 \pm 0.008$	$(3.8 \pm 0.5) \times 10^{-4} e^2 \cdot \text{fm}^2$	$(8.3 \pm 1.0) \times 10^{-4}$
$R \rightarrow 5.62$	E1	$0.47 \pm 0.07$	$0.097 \pm 0.014$	$(9.2 \pm 1.3) \times 10^{-4} e^2 \cdot \text{fm}^2$	$(2.0 \pm 0.3) \times 10^{-3}$
$R \rightarrow 7.42$	M1	$1.5 \pm 0.2$	$0.31 \pm 0.04$	$1.16 \pm 0.15 \mu_N^2$	$0.65 \pm 0.08$
$R \rightarrow 7.83$	M1	$0.04 \pm 0.01$	$0.008 \pm 0.002$	$0.050 \pm 0.012 \mu_N^2$	$0.027 \pm 0.006$

ELEM. SYM.	A	Z
Ne	20	10
METHOD		REF. NO.
78 Da 5		hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
A,GO	LFT	11	D	8	SCD-D		DST
		(11.278)		(8.18)			

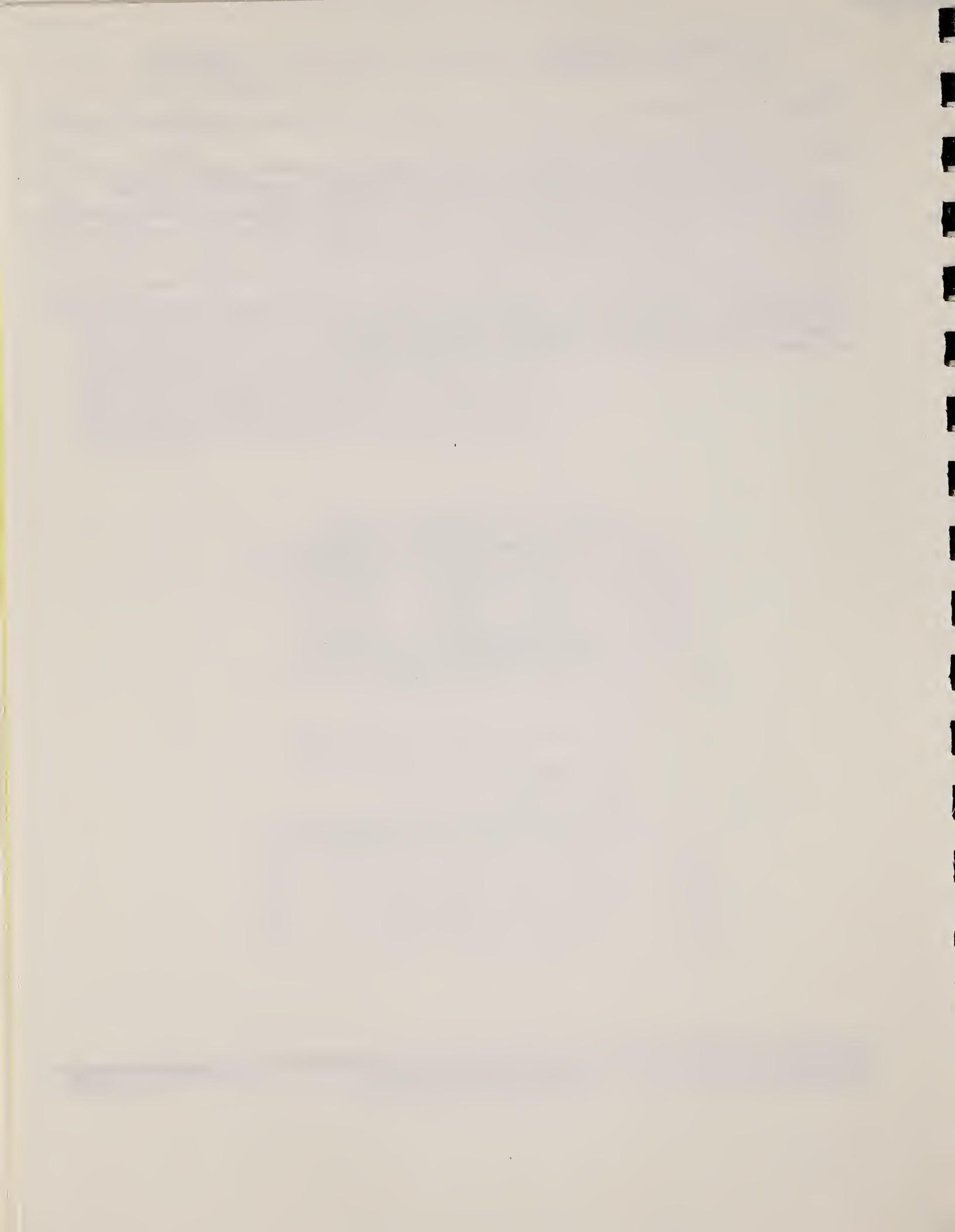
The properties of the  $1^-, T = 1$  state of  $^{20}\text{Ne}$  at  $11278 \pm 4$  keV excitation were studied by means of the  $^{16}\text{O}(\alpha, \gamma)^{20}\text{Ne}$  reaction. The level parameters determined for this state are not in complete agreement with those reported in a recent study. The implication of this discrepancy for the feasibility of a measurement of parity nonconservation in  $^{20}\text{Ne}$  is discussed.

TABLE I. Properties of the lowest  $1^-, T=1$  state of  $^{20}\text{Ne}$ .

Reference	$\omega\gamma_0^{c.m.}$ (eV)	$E_x$ (keV)
Ref. 3	$0.7 \pm 0.3^*$	$11270 \pm 30$
Ref. 1	$0.58 \pm 0.05$	$11259 \pm 8$
Ref. 12	$1.2 \pm 0.3$	
Present work	$1.0 \pm 0.3$	$11278 \pm 4$

\*The value quoted in Ref. 3 has been multiplied by  $\frac{16}{20}$  to express it in the center-of-mass system.

- 1 D.J. Steck, Phys. Rev. C 17, 1034 (1978)  
 3 J.D. Pearson and R.H. Spear, Nucl. Phys. 54, 434 (1964)  
 12 K. Fifield, Nuclear Physics Laboratory, Oxford University, private communication



ELEM. SYM.	A	Z
Ne	20	10

METHOD

REF. NO.  
78 Sz 7hmg  
11/18/80

Page 1 of 3

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,E/	FMF	12-23	D	59-120	MAG-D	---	DST

Electrons at five energies between 60 and 120 MeV were used to study the giant electric-dipole and quadrupole resonances in  $^{20}\text{Ne}$ . Prominent electric-dipole peaks were found at 17.7, 19.1, 20.2, and 23 MeV in good agreement with photoreaction results. In addition our analysis reveals weaker fragmented electric-dipole strength in the region between 12.5 and 15 MeV. Prominent electric-quadrupole peaks were found at 13.0, 13.7, and 16.2 MeV, and a broad peak was found from 14.2 to 15.9 MeV. Two different analyses reveal a broad quadrupole excitation between 16 and 25 MeV. The dipole and quadrupole resonances deplete about 65% and 100% of the energy-weighted sum rule, respectively.

TABLE I. Reduced transition probabilities  $B(\text{CL})^\dagger$  obtained by (A) photoreaction subtraction and (B) multipole expansion using the Goldhaber-Teller model and the Steinwedel-Jensen model (square brackets) for the  $B(\text{C}1)^\dagger$  and the Tassie model for the  $B(\text{C}2)^\dagger$ . Model errors are not included.

Dipole reduced transition probabilities					
A. Photoreaction subtraction (Ref. 12)			B. Multipole expansion		
$E_x$ (MeV)	$B(\text{C}1)^\dagger$ ( $e^2 \text{ fm}^2$ )		$B(\text{C}1)^\dagger$ ( $e^2 \text{ fm}^2$ )		
10-16			0.33 $\pm$ 0.02		
			[0.35 $\pm$ 0.02]		
16-25	1.65 $\pm$ 0.13		2.1 $\pm$ 0.1		
			[2.2 $\pm$ 0.1]		
16-17.2	0.16		0.17 $\pm$ 0.02		
17.7	0.29		0.20 $\pm$ 0.02		
19.1	0.34		0.33 $\pm$ 0.03		
20.2	0.33		0.43 $\pm$ 0.04		
20.9-25.0	0.53		0.99 $\pm$ 0.10		
Quadrupole reduced transition probabilities					
A. Photoreaction subtraction			B. Multipole expansion		
$E_x$ (MeV)	$B(\text{C}2)^\dagger$ ( $e^2 \text{ fm}^4$ )		$E_x$ (MeV)	$B(\text{C}2)^\dagger$ ( $e^2 \text{ fm}^4$ )	
1.63	188 $\pm$ 9 <sup>a</sup>		10-13	110 $\pm$ 5	
7.80	18.1 $\pm$ 0.9			[105 $\pm$ 5]	
10-16	128 $\pm$ 19		10.4-11.2	10 $\pm$ 1	
			11.9	11 $\pm$ 1	
			13.0	19 $\pm$ 2	
			13.7	17 $\pm$ 2	
			14.5, 15.0, 15.4	30 $\pm$ 3	
			16.2	24 $\pm$ 2	
16-25	119 $\pm$ 18		18-25	88 $\pm$ 5	
				[72 $\pm$ 5]	

<sup>a</sup>Obtained by using Helm model (Ref. 24) in a comparison to the elastic scattering.

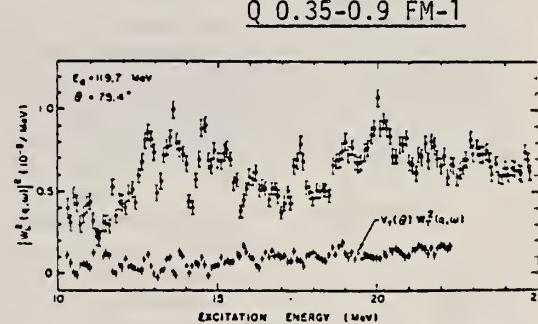


FIG. 2. The radiatively unfolded longitudinal (solid points) and transverse (open circle) differential form factors in the giant resonance region of  $^{20}\text{Ne}$  obtained by scattering 119.7 MeV electrons through 75.4°. The transverse form factor  $V_L(0)W_T^2(q, \omega)$  was obtained by a matching- $q$  experiment.

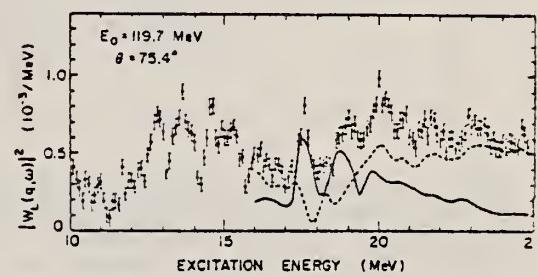


FIG. 3. The longitudinal differential form factor of  $^{20}\text{Ne}$  obtained by scattering 119.7 MeV electrons through an angle of 75.4° is shown by the points with error bars. The dipole contribution obtained as described in Sec. IIIA is shown by the solid curve, and the residual contribution is shown by the dashed curve.

(OVER)

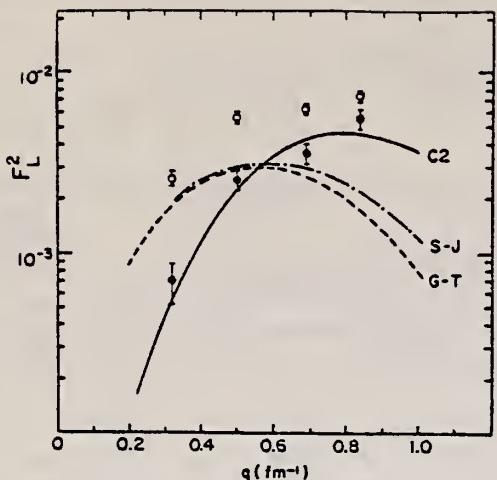


FIG. 4. The longitudinal form factor integrated from 16 to 26 MeV is shown by the open circles and the residual form factor obtained by the subtraction of the dipole form factor is shown by the black circles. The residual form factors can be explained by quadrupole excitations. The curve labeled GT (SJ) is the dipole form factor calculated using the Goldhaber-Teller (Steinwedel-Jensen) model.

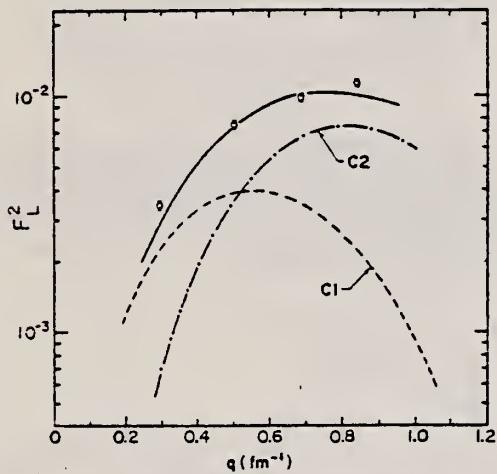


FIG. 6. The results of the multipole expansion method, showing the longitudinal form factor squared integrated from 10 to 25 MeV. The dashed, dash-dotted, and solid lines are dipole and quadrupole components, and their sum, respectively.

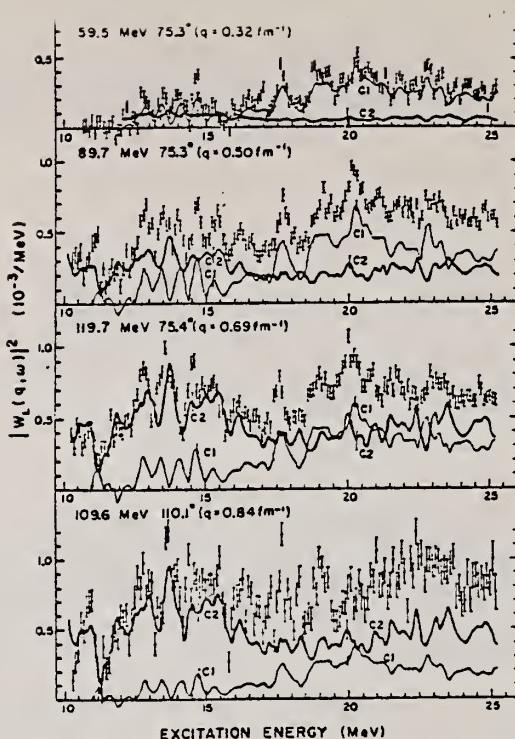


FIG. 5. The longitudinal differential form factor of  $^{20}\text{Ne}$  at various momentum transfers. The points with error bars show the experimental results. The thin curve shows the dipole form factor and the thick curve shows the quadrupole form factor obtained by the multipole expansion method. The occasional error bars on the C1 and C2 curves indicate statistical errors only. In addition there are model dependent and unexplored systematic errors.

TABLE III. The percentages of the electric-quadrupole isoscalar energy-weighted sum rule  $S_2$  (Isoscalar) as obtained by the multipole expansion method, in comparison with  $(\alpha, \alpha')$  results (Ref. 7), and calculations using an excited core model (Ref. 35). Results are also given assuming the excitations were of monopole rather than of quadrupole character. Model errors are not included in the present results.

	Quadrupole $(\alpha, \alpha')$				Theory	
	$E_x$ (MeV)	$S_2$ (Isoscalar) (%)	$E_x$ (MeV)	$S_2$ (Isoscalar) (%)	$E_x$ (MeV)	$S_2$ (Isoscalar) (%)
1.63	$8.2 \pm 0.5$	1.63	16.3			
7.80	$3.7 \pm 0.3$					
10-18	$41 \pm 2$	12.9-16.4	19.5		15-29	29.8
10.4-11.2	2.8				15.8	7.9
11.9	3.3				21.1	8.9
13.0	6.4				23.5	1.1
13.7	6.2	12.9	4		25.5	4.0
			13.9	5	26.1	4.1
					27.2	0.19
14.2-15.9	12	15.2	6		28.1	2.9
15.9-18.0	11	16.4	$\leq 4.5$		28.9	0.66
18-25	$50 \pm 3$	18.1-28.2	$35.7 \pm 1$			
Monopole (Isoscalar and isovector)						
	$E_x$ (MeV)	$S_0$ (%)	$E_x$ (MeV)	$S_0$ (%)		
10-18		34	15-30	40		
18-25		40	15.0	6.5		
			25.2	3.3		
			26.6	27.7		
			29.9	2.4		

METHOD

REF. NO.

Page 3 of 3

78 Sz 7

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	

TABLE II. The percentages of the electric-dipole isovector energy-weighted sum rule  $S_1$  (Isovector) as obtained by the multipole expansion method, in comparison with the results of photoreactions. Model errors are not included.

$E_x$ (MeV)	Dipole		Photoreaction $S_1$ (Isovector) (%)
	Present results $S_1$ (Isovector) (%)	Photoreaction $S_1$ (Isovector) (%)	
10-15.6	6.0 ± 4		
11.2	0.39		
12.3	1.0		
13.4	1.1		
14.1	1.2		
14.7	1.4		
15.3	0.91		
15.6-25.0	59 ± 3		
15.6-17.0	3.6	3.5	
17.7	4.8	6.9	
19.1	8.3	8.6	
20.2	11.7	8.8	
20.9-25.0	30.6	16.1	

able fragmentation between 11 and 17 MeV, although the presence of some monopole strength in this region cannot be excluded. Thus the quadrupole strength in  $^{20}\text{Ne}$  spreads over a wide energy region and is not concentrated in a well-defined GQR as in medium and heavy nuclei. This seems to be a feature of other light nuclei.

An excited core model calculation for  $^{20}\text{Ne}$ , wherein the low-lying excited states of the valence nucleons are coupled to the giant multipole resonance of the  $^{16}\text{O}$  core, was performed by Knüpfer *et al.*<sup>33</sup> We have compared the results of this calculation with our experimental results in Table III. One of the characteristic results of this calculation is the splitting of C0 and C2 strength into a higher and a lower energy component (14 and 21 MeV), which is in qualitative agreement with the present experimental results as well as the results of  $(\alpha, \alpha')$  experiments. The splitting of the GQR in deformed nuclei such as  $^{20}\text{Ne}$  has also been examined by the coupling of

ELEM. SYM.	A	Z
Ne	20	10
METHOD	REF. NO.	.

80 Ma 5 hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,A	LFT	7	D	3	SCD-D		DST
		(7.158)		(3.036)			

In an alpha capture experiment on an  $^{16}\text{O}$  gas target, the  $3^+$ , 7.156 MeV state in  $^{20}\text{Ne}$  has been observed to decay to the  $1^-$ , 5.782 MeV and the  $4^+$ , 4.248 MeV states with gamma ray branches of  $45 \pm 5\%$  and  $55 \pm 5\%$ , respectively. The strengths of the 1374 and 2908 keV transitions were deduced to be  $B(E2) = 51 \pm 8$  W.u. and  $B(E1) = 79 \pm 9$   $\mu\text{W.u.}$ , respectively. The strongly enhanced  $E2$  rate for the  $3^+$  to  $1^-$  transition is convincing evidence for these two states being the first members of this  $K^+ = 0^+$  band in  $^{20}\text{Ne}$ . From resonance scattering experiments, the alpha widths for these two states were determined to be  $28 \pm 3$  eV and  $8.1 \pm 0.3$  keV, respectively; values in agreement with cluster calculations of alpha widths in  $^{20}\text{Ne}$ .

LFT LIMIT 7.156 MEV

[NUCLEAR REACTIONS Measured  $\sigma(E, \theta)$  for  $^{16}\text{O}(\alpha, \alpha)^{16}\text{O}$  and  $\sigma(E_R)$  for  $^{16}\text{O}(\alpha, \gamma)^{20}\text{Ne}$ ; deduced  $\Gamma_\alpha$  for  $E_\alpha = 5.782$  and 7.156 MeV and radiative transition rates from  $E_\gamma = 7.156$  MeV.]

TABLE I. Transitions from the  $3^+$  state at  $E_\gamma = 7.156$  MeV excited in the  $^{16}\text{O}(\alpha, \gamma)^{20}\text{Ne}$  reaction at  $E_\alpha = 3.036$  MeV. Energies with errors are for gamma rays actually observed. The strengths are deduced assuming pure transitions.

Final state		$E_\gamma$ (keV)	$J^\pi$	$E_\gamma$ (keV)	$\Gamma_\gamma$ (meV)	Strength	
$E_\gamma$ (keV)	$J^\pi$					$\Gamma_\gamma$ (meV)	Strength
0	$0^+$	7156		<0.05	<5.0	W.u. E3	
1634	$2^+$	5523		<0.08	<0.9	$\mu\text{W.u. } E1$	
4248	$4^+$	2908.4 $\pm$ 0.4		$0.97 \pm 0.11$	$79 \pm 9$	$\mu\text{W.u. } E1$	
4963	$2^-$	2188		<0.05	<0.23	$m\text{W.u. } M1$	
5621	$3^-$	1535		<0.05	<0.66	$m\text{W.u. } M1$	
5782	$1^-$	1374.3 $\pm$ 0.4		$0.64 \pm 0.10$	$51 \pm 8$	W.u. $E2$	

METHOD				REF. NO.	
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE RANGE	TYPE RANGE	
G, F18	YLD	THR-60	C 30-60	ACT-I	4PI

The production rates of  $^{18}\text{F}$  by the  $^{20}\text{Ne}(\gamma, pn)^{18}\text{F}$  plus  $^{20}\text{Ne}(\gamma, 2n)^{18}\text{Ne} \rightarrow ^{18}\text{F}$ ,  $^{23}\text{Na}(\gamma, zn)^{18}\text{F}$ , and  $^{19}\text{F}(\gamma, n)^{18}\text{F}$  reactions were determined as a function of the maximum bremsstrahlung energies between 30 and 60 MeV. In addition, a simple and fast method to prepare anhydrous  $\text{H}^{18}\text{F}$  was studied by using  $\text{KHF}_2$  target.

TABLE I. Photonuclear reactions for  $^{18}\text{F}$  production

Target nuclide (abundance, %)	Reaction type	Threshold energy (MeV)	Product nuclide
$^{20}\text{Ne}$ (90.51)	$(\gamma, 2n)$	28.50	$^{18}\text{Ne} \rightarrow ^{18}\text{F}$
$^{21}\text{Ne}$ (0.27)	$(\gamma, 3n)$	35.27	$^{18}\text{Ne} \rightarrow ^{18}\text{F}$
$^{22}\text{Ne}$ (9.22)	$(\gamma, 4n)$	45.63	$^{18}\text{Ne} \rightarrow ^{18}\text{F}$
$^{20}\text{Ne}$ (90.51)	$(\gamma, pn)$	23.26	$^{18}\text{F}$
$^{21}\text{Ne}$ (0.27)	$(\gamma, p2n)$	29.93	$^{18}\text{F}$
$^{22}\text{Ne}$ (9.22)	$(\gamma, p3n)$	40.38	$^{18}\text{F}$
$^{23}\text{Na}$ (100)	$(\gamma, zn)$	20.89	$^{18}\text{F}$
$^{19}\text{F}$ (100)	$(\gamma, n)$	10.43	$^{18}\text{F}$

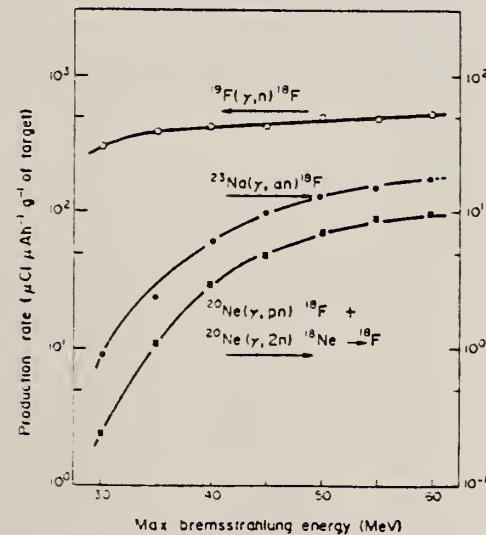


FIG. I. Production rates of  $^{18}\text{F}$  on Ne, Na and F targets as a function of the maximum bremsstrahlung energy



ELEM. SYM.	A	Z
Ne	20	10

METHOD

REF. NO.

81 A1 5

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, 1N,	ABX	16-29	C	16-29	BF3-I		4PI

**Abstract:** The photoneutron cross section of  $^{20}\text{Ne}$  has been measured over a photon energy range 16 to 29 MeV in steps of 100 keV. The giant dipole resonance is resolved into three strong peaks below 21 MeV and at least two broader resonances at higher excitations. This structure is consistent with earlier measurements of poorer resolution and shows a correlation with the recent calculations of Schmid and Do Dang. Comparisons with high-resolution neutron time-of-flight and electron scattering data indicate the existence of regions of structure, roughly 2-3 MeV wide, which exhibit localised characteristics related to the excitation mechanisms. The role of deformation and configuration splitting effects in the cross section is discussed and possible directions of further study are noted which might clarify the situation more fully.

#### ENRICHED NEON-20 TARG

E NUCLEAR REACTIONS  $^{20}\text{Ne}(\gamma, n)$ , bremsstrahlung,  $E = 16 - 29$  MeV; measured  $\sigma(E)$ ; deduced  $\sigma$ ,  $\sigma^*$  and differential form factor.  $\text{BF}_3$  detector. Enriched target.

TABLE I  
 Photoneuclear integrated cross sections

Ref.	Reaction	Upper energy limit (MeV)	Integrated cross section (MeV · mb)	Fractional dipole sum *
Melbourne	$(\gamma, n)$	20.6	$20 \pm 2$	0.07
		26.7	$49 \pm 5$	0.16
		28.5	$58 \pm 6$	0.19
Veyssiére <i>et al.</i> <sup>3)</sup>	$(\gamma, n)$	20.6	15.8	0.05
		26.7	$42 \pm 3$	0.14
Woodworth <i>et al.</i> <sup>5)</sup>	$(\gamma, n)$	31.0	56.9-76.8	0.19-0.26
Ferguson <i>et al.</i> <sup>15)</sup>	$(\gamma, n)$	27	52	0.17
Gorbunov <i>et al.</i> <sup>38)</sup>	$(\gamma, n)$	170	115	0.38
Dodge and Barber <sup>6)</sup>	$(\gamma, p)$	27	$65_{-10}^{+13}$	0.22
Hofmann <i>et al.</i> <sup>20)</sup>	$(\gamma, p)$	32.5	$61 \pm 11$	0.20
Komar and Iavor <sup>39)</sup>	$(\gamma, p)$	80	$160 \pm 80$	0.53
Gorbunov <i>et al.</i> <sup>38)</sup>	$(\gamma, p)$	170	165	0.55
Tanner <i>et al.</i> <sup>22)</sup>	$(\gamma, p_0)$	20.5	$28 \pm 9$	0.09
Segel <i>et al.</i> <sup>7)</sup>	$(\gamma, p_0)$	25.7	25	0.08
Gorbunov <i>et al.</i> <sup>38)</sup>	$(\gamma, \text{tot})$	170	600	2

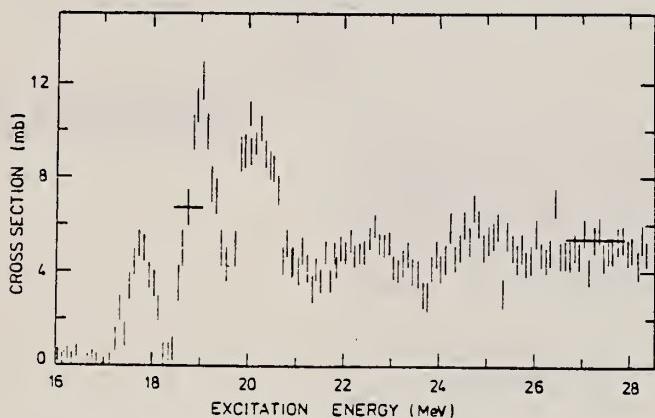
\* Dipole sum =  $60 NZ/A = 300$  MeV · mb.

(OVER)

TABLE 3

Comparison of the integrated cross section under the 17.6 MeV peak for the  $^{20}\text{Ne}(\gamma, n_0 + n_1 + n_2)$  reactions

Ref.	$\int \sigma dE (\text{MeV} \cdot \text{mb})$
present experiment	$3.3 \pm 0.3$
Woodworth <i>et al.</i> <sup>5)</sup>	$3.3 \pm 0.5$
Veyssi��re <i>et al.</i> <sup>3)</sup>	$2.6 \pm 0.3$

Fig. 3. The measured  $^{20}\text{Ne}(\gamma, tn)$  cross section. The vertical bars indicate statistical errors while the horizontal bars show the variation of resolution over the energy range.

N<sub>e</sub>  
A=22

N<sub>e</sub>  
A=22

N<sub>e</sub>  
A=22



Elem. Sym.	A	Z
Ne	22	10

Method 500 keV Cockcroft-Walton cascade generator; photodisintegration;  
 $\text{Li}^7(\text{p},\gamma)$  reaction.

Ref. No.	
59 Ha 1	EH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$\text{Ne}^{22}(\gamma,\alpha)$	17.63 14.8					<u>Cross Section</u> 0.76 mb <u>State</u> ground state $\alpha$ 's detected in neon filled proportional counters.

ELEM. SYM.	Ne	22	10
REF. NO.	60 Ko 2	NVB	

METHOD Synchrotron; proton, n-p spectra; angular distribution; cross sections; cloud chamber

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, P	SPC	THR-90	C	90	CCH-D	2-24	DST
G, NP	SPC	THR-90	C	90	CCH-D	2-20	DST

89% Ne<sup>22</sup>, 10% Ne<sup>20</sup>, 1% Ne<sup>21</sup>

SEP ISOTPS

$$\int_0^{90} \sigma_t dE = 0.44 \text{ MeV-b}$$

In Figure 3:

$$\frac{d\sigma}{d\Omega} = 0.29 + 0.11 \sin^2 \theta$$

In Figure 4:

$$\frac{d\sigma}{d\Omega} = [0.22 + 0.07 \sin^2 \theta] + [0.085 \cos \theta]$$

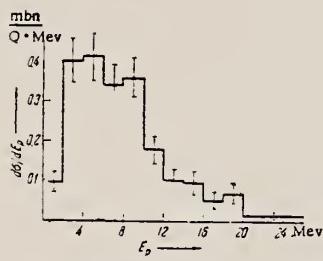


Fig. 1. Energy distribution of the photoprotons from the reaction ( $\gamma$ , p).

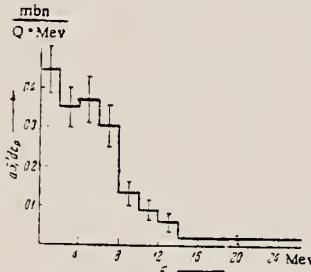


Fig. 2. Energy distribution of the photoprotons from the reaction ( $\gamma$ , pn).

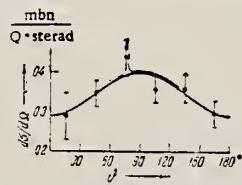


Fig. 3. Angular distribution of the photoprotons from the reaction ( $\gamma$ , p) with energies exceeding 0.5 Mev.

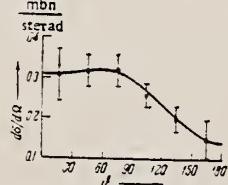


Fig. 4. Angular distribution of the photoprotons from the reaction ( $\gamma$ , pn) with energies exceeding 0.5 Mev.

TABLE 1

Relative Outputs for the Photodisintegration of Neon

Reaction	Ne <sup>20</sup> thresh. Mev.	Ne <sup>22</sup> thresh. Mev.	Ne <sup>20</sup> output %	Ne <sup>22</sup> output %
$\gamma$ , p	12.0	15.3	39	22
$\gamma$ , n	16.0	10.4	17	30
$\gamma$ , nn	(24.1)	(17.1)	—	—
$\gamma$ , a	4.7	9.7	1	7
$\gamma$ , pn	23.3	23.4	6	18
$\gamma$ , np	16.0	25.6	22	4.5
$\gamma$ , nn	21.2	17.7	7.5	8.5
Other stars	—	—	7.5	13
No. of cases			1928	1759
$\int dE$ , Mev. mbn			430	440

METHOD

REF. NO.

68 Gr 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
A,G	LFT	12,13	D	2,3	NAI-D	8-13	DST

12,13=11.89,12.28 MEV

TABLEAU I

CARACTÉRISTIQUES DES NIVEAUX ÉTUDIÉS  
 LES VALEURS DE  $E_{\text{rés}}$ ,  $E_x$  ET  $\Gamma$  ONT ÉTÉ RELEVÉES DANS LES RÉFÉRENCES [4, 5]

$E_{\text{rés}}$ MeV	$E_x$ ( $^{22}\text{Ne}$ ) MeV	TRANSITION $\gamma_0$				TRANSITION $\gamma_1$			
		$J^\pi$	$\Gamma$ keV	$\Gamma_{\gamma_0}$ eV	$ M ^2$ UNITÉS DE WEISSKOPF	$x$ = COEFFICIENT DE MÉLANGE M2/E1	$\Gamma_{\gamma_1}$ eV	$ M ^2$ UNITÉS DE WEISSKOPF	$\Gamma_{\gamma_0}/\Gamma_{\gamma_1}$
		—	—	—	—	—	—	—	—
2,71	11,89	1-	13	0,36 ± 0,14	$0,38 \times 10^{-3}$	— 0,267 ± 0,047	0,35 0,11	$0,28 \times 10^{-3}$	1,09 ± 0,13
3,19	12,28	1-	80	2,4 ± 1,0	$2,1 \times 10^{-3}$	— 0,327 ± 0,067	2,3 1,0	$1,7 \times 10^{-3}$	1,04 ± 0,14

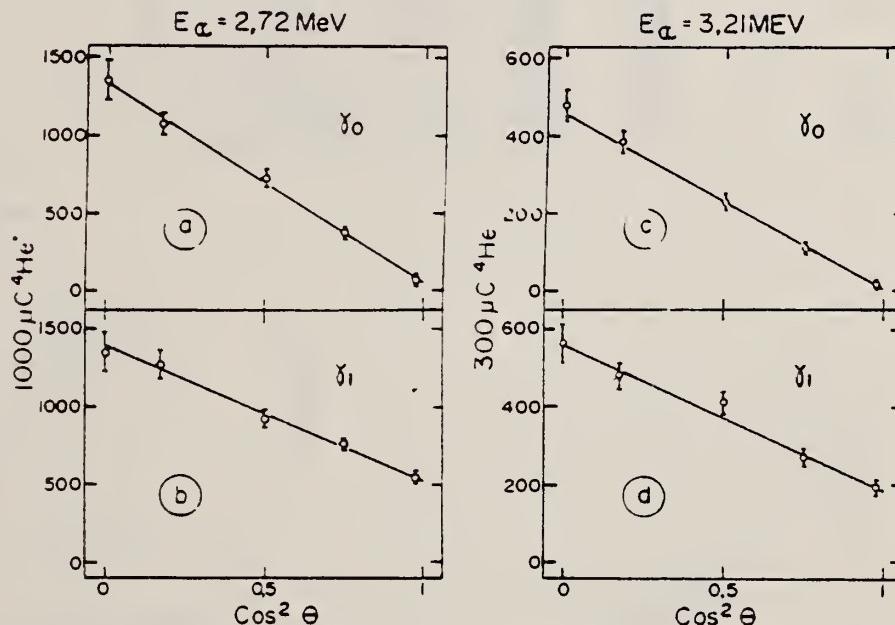


FIG. 2. — Distributions angulaires des rayonnements  $\gamma_0$  et  $\gamma_1$ . Les barres d'erreur sont d'origine statistique et tiennent compte des diverses corrections appliquées. Les droites représentent les ajustements obtenus par la méthode des moindres carrés.

METHOD					REF. NO.		
					69 Ho 1	egf	
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XP	ABY	THR-33	C	24-33	SCI-D	3-14	90

Tabelle 1. Daten zu den einzelnen Reaktionen. Die Werte für den integrierten Wirkungsquerschnitt wurden unter der Annahme ausschließlicher Grundzustandsübergänge berechnet. Für  $^{23}\text{Na}$  und  $^{39}\text{K}$  als Ausnahme s. Text

Target	Anreicherungsgrad %	( $\gamma$ , p)-Schwelle MeV	Druck oder Dicke	Endenergie MeV	Zahl gemess. Protonen	Ausbeute $\mu\text{b}$ MeV sr	$\int \sigma(E) dE$ Figur
						MeVmb	
$^{18}\text{O}$	99	16,0	230 Torr	32,5	36074	$58 \pm 7$	$38 \pm 6$ 1, 2
$^{20}\text{Ne}$	90,9	12,8	450 Torr	28,0	3175	$7,4 \pm 1$	—
			610 Torr	32,5	6293	$14,9 \pm 2$	$61 \pm 11$ 5, 6
$^{22}\text{Ne}$	99,9	15,3	240 Torr	24,0	1960	$2,3 \pm 0,4$	—
				28,0	4790	$3,6 \pm 0,6$	—
				32,5	5210	$6,7 \pm 0,9$	$45 \pm 8$ 4, 5
$^{23}\text{Na}$	100	8,8	$65\mu$	24,0	14182	$6,3 \pm 1,0$	—
			$60\mu$	32,5	11152	$12,8 \pm 2,0$	$117 \pm 30$ 7
$^{36}\text{Ar}$	99	8,5	250 Torr	32,5	45173	$57 \pm 6$	$270 \pm 40$ 8, 10
$^{40}\text{Ar}$	99,6	12,5	230 Torr	32,5	29559	$14,2 \pm 1,5$	$104 \pm 15$ 9, 11
$^{39}\text{K}$	93,1	6,4	$80\mu$	24,0	24230	$17,4 \pm 2,8$	—
			$90\mu$	32,5	24941	$41,9 \pm 6,7$	$405 \pm 100$ 12
$^{44}\text{Kr}$	99	10,7	170 Torr	32,5	35515	$12,7 \pm 2,0$	$80 \pm 20$ 14
Kr	natürl.	10	170 Torr	32,5	13570	$12,5 \pm 2,0$	$75 \pm 20$ 13
Ne	natürl.	9	150 Torr	32,5	7553	$7,6 \pm 0,9$	$40 \pm 7$ 15

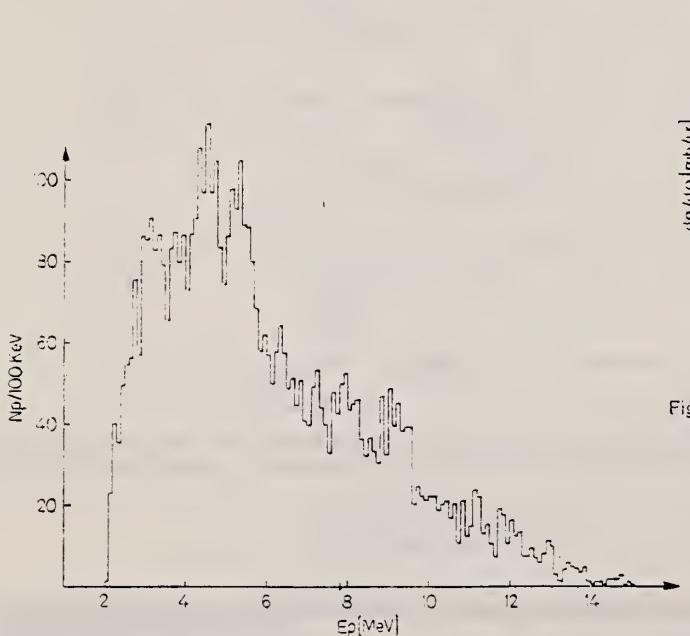


Fig. 3. Energieverteilung der Photoprotonen aus  $^{22}\text{Ne}$ .  $E_0 = 32,5$  MeV

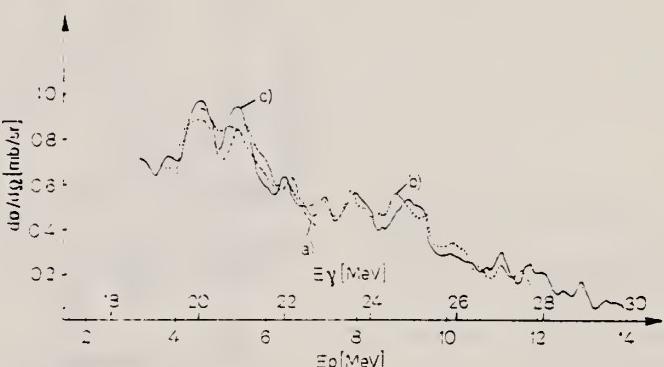


Fig. 4. Der ( $\gamma$ , p)-Wirkungsquerschnitt für  $^{22}\text{Ne}$ , berechnet aus den Bestrahlungen bei a 24 MeV, b 28 MeV und c 32,5 MeV

ELEM. SYM.	A	-
Ne	22	10

METHOD					REF. NO.
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE	RANGE	
E, E/	FMF	1 (1.275)	D	77-115	MAG-D
					DST

LEVEL AT 1.275 MEV

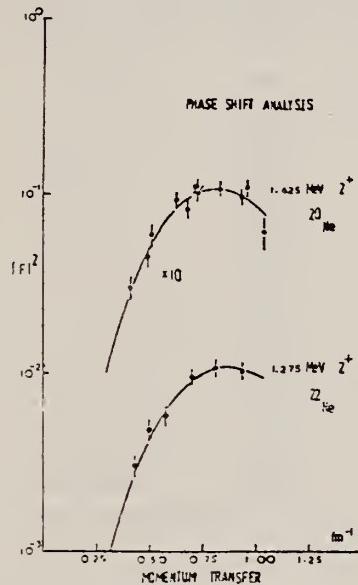


FIG. 6. The result of best fits to the 1.625 MeV,  $2^+$  state in  $^{20}\text{Ne}$  and 1.275 MeV,  $2^+$  state in  $^{22}\text{Ne}$ . Tassie model has been used in a phase shift code for the fits.

TABLE 2. Experimental form factors for the 1.275 MeV state in  $^{22}\text{Ne}$

$E_0$ (MeV)	$\theta$ (deg)	Square of experimental form factor $\times 10^3$ (errors in %)
60.3	90	3.12 (15)
60.3	110	4.96 (15)
114.7	60	5.73 (15)
114.7	75	9.54 (10)
114.7	90	10.52 (10)
114.7	110	10.20 (10)



X.K. Maruyama, R.A. Lindgren, W.L. Bendel, E.C. Jones, Jr.,  
and L.W. Fagg  
Phys. Rev. C10, 2257 (1974)

ELM. SYM.	Ne	22	10
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## METHOD

REF. NO.

74 Ma 8

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	ABX	0 - 19	D	37 - 60	MAG-D		180

TABLE III. Summary of results of this experiment showing excitation energy, spin and parity, transition radius, reduced matrix elements, electromagnetic width to the ground state, and transition strength. The Weisskopf unit is defined in Ref. 12. Where two  $J^\pi$  assignments are made, the data are compatible with either designation.

B(EL), J-PI

FOR ERRATUM SEE 78 Ma 6

Level energy (MeV)	$J^\pi$	$R$ (fm)	$B(\lambda L)$ ( $e^2 \text{ fm}^2 L$ or $\mu_0^2 \text{ fm}^2 L^{-2}$ )	$\Gamma_\gamma$ (eV)	Transition strength (Weisskopf units)
5.31 ± 0.03	1 <sup>+</sup>	2.51 <sup>± 0.18</sup> <sub>± 0.31</sub>	0.074 ± 0.013	0.127 ± 0.022	0.040 ± 0.007
6.82 ± 0.03	1 <sup>+</sup>	2.24 <sup>± 0.24</sup> <sub>± 0.42</sub>	0.166 ± 0.026	0.611 ± 0.096	0.092 ± 0.014
9.14 ± 0.03	1 <sup>+</sup>	2.85 <sup>± 0.11</sup> <sub>± 0.14</sub>	0.320 ± 0.030	2.83 ± 0.26	0.176 ± 0.016
10.84 ± 0.06	1 <sup>+</sup>	2.86 <sup>± 0.25</sup> <sub>± 0.50</sub>	0.045 <sup>± 0.015</sup> <sub>± 0.012</sub>	0.66 <sup>± 0.11</sup> <sub>± 0.11</sub>	0.025 <sup>± 0.009</sup> <sub>± 0.006</sub>
10.08 ± 0.03	1 <sup>+</sup>	3.15 <sup>± 0.15</sup> <sub>± 0.19</sub>	0.095 ± 0.016	1.13 ± 0.14	0.042 ± 0.007
	1 <sup>-</sup>	1.89 <sup>± 0.54</sup> <sub>± 0.89</sub>	0.031 <sup>± 0.003</sup> <sub>± 0.003</sub>	33 <sup>± 10</sup> <sub>± 10</sub>	0.061 <sup>± 0.017</sup> <sub>± 0.014</sub>
12.56 ± 0.06	1 <sup>+</sup>	3.14 <sup>± 0.32</sup> <sub>± 0.56</sub>	0.038 <sup>± 0.011</sup> <sub>± 0.018</sub>	1.34 <sup>± 0.55</sup> <sub>± 0.55</sub>	0.032 <sup>± 0.014</sup> <sub>± 0.014</sub>
	1 <sup>-</sup>	2.60 <sup>± 0.51</sup> <sub>± 2.50</sub>	0.21 <sup>± 0.011</sup> <sub>± 0.009</sub>	44 <sup>± 11</sup> <sub>± 11</sub>	0.042 <sup>± 0.026</sup> <sub>± 0.016</sub>
7.63 ± 0.03	2 <sup>-</sup>	3.69 ± 0.30	10.1 <sup>± 2.5</sup> <sub>± 2.3</sub>	(2.34 <sup>± 0.57</sup> <sub>± 0.57</sub> ) × 10 <sup>-3</sup>	0.78 <sup>± 0.19</sup> <sub>± 0.17</sub>
8.54 ± 0.03	2 <sup>-</sup>	3.07 <sup>± 0.53</sup> <sub>± 1.19</sub>	3.5 <sup>± 1.1</sup> <sub>± 1.1</sub>	(1.46 <sup>± 0.57</sup> <sub>± 0.57</sub> ) × 10 <sup>-3</sup>	0.27 <sup>± 0.15</sup> <sub>± 0.15</sub>
11.86 ± 0.05	2 <sup>-</sup>	4.10 <sup>± 0.35</sup> <sub>± 0.35</sub>	6.9 <sup>± 1.0</sup> <sub>± 1.0</sub>	(1.49 <sup>± 0.57</sup> <sub>± 0.57</sub> ) × 10 <sup>-3</sup>	0.52 <sup>± 0.22</sup> <sub>± 0.18</sub>

TABLE II. Reduced matrix element extracted from fitting the data assuming an electric quadrupole transition.

Level energy (MeV)	$B(E2)$ ( $e^2 \text{ fm}^2$ )
5.31 ± 0.03	22.9 ± 5.6
6.82 ± 0.03	32.0 ± 6.2
9.14 ± 0.03	38.2 ± 4.9
10.08 ± 0.08	8.0 <sup>± 1.5</sup> <sub>± 1.5</sub>
10.84 ± 0.06	3.5 ± 0.9
12.56 ± 0.06	3.0 <sup>± 1.9</sup> <sub>± 1.4</sub>

TABLE I. Values of differential cross sections for states observed in this experiment in units of  $10^{-32}$   $\text{cm}^2/\text{sr}$ . The incident electron energies are 37.39, 50.65, and 60.85 MeV.

Excitation energy (MeV)	$(d\sigma/d\Omega)_{\gamma\gamma}$	$(d\sigma/d\Omega)_{\gamma 0}$	$(d\sigma/d\Omega)_{00}$
1.27 ± 0.15	≤ 0.16	≤ 0.14	≤ 0.020
5.31 ± 0.03	0.268 ± 0.033	0.185 ± 0.020	0.109 ± 0.012
6.82 ± 0.03	0.640 ± 0.069	0.510 ± 0.053	0.337 ± 0.034
7.63 ± 0.03	0.191 ± 0.029	0.209 ± 0.024	0.171 ± 0.021
8.54 ± 0.03	≤ 0.19	0.116 ± 0.015	0.127 ± 0.017
9.14 ± 0.03	0.992 ± 0.103	0.607 ± 0.062	0.326 ± 0.035
10.08 ± 0.08	0.237 ± 0.036	0.107 ± 0.016	0.068 ± 0.011
10.84 ± 0.06	0.134 ± 0.028	0.092 ± 0.012	0.039 ± 0.008
11.86 ± 0.05	0.097 ± 0.030	0.107 ± 0.016	0.072 ± 0.010
12.56 ± 0.06		0.057 ± 0.017	0.040 ± 0.009
13.55 ± 0.10			0.029 ± 0.009
14.49 ± 0.15			0.163 ± 0.020
15.68 ± 0.25			0.068 ± 0.015
16.93 ± 0.20			
17.43 ± 0.10			0.157 ± 0.024
17.98 ± 0.08			
18.73 ± 0.20			0.112 ± 0.018

(over)

TABLE IV. Excitation energies (MeV) and spin and parity of states observed in the present experiment, compared with states observed in other experiments.

Present work, level energy, and $J^\pi$	$(t, p)^a$	$(d, p)^b$	$(^7\text{Li}, t)^c$	$(t, \alpha)^d$	Currently-accepted <sup>e</sup> level energy and $J^\pi$
$1.27 \pm 0.15$					$1.275 \quad 2^+$
$5.31 \pm 0.03 \quad 1^+$		$5.331$		$5.350$	$5.335 \pm 0.009 \quad (1, 2)^+$
		$5.340$	$5.359$	$5.370$	$5.360 \pm 0.003 \quad 2^+$
		$6.823$	$6.821$	$6.820$	$6.819 \pm 0.007 \quad 2^+$
$6.82 \pm 0.03 \quad 1^+$	$6.860$	$6.858$		$6.840$	$6.855 \pm 0.003 \quad (1, 2)^+$
		$7.633$	$7.630$	$7.640$	$7.632 \pm 0.003 \quad (1, 2)^+$
$7.63 \pm 0.03 \quad 2^-$	$7.663$	$7.658$			$7.660 \pm 0.003 \quad (0 - 3)^-$
$8.54 \pm 0.03 \quad 2^-$		$8.548$			$8.548 \pm 0.010 \quad (0 - 4)^+$
		$8.575$	$8.585$	$8.590$	$8.583 \pm 0.003 \quad (1, 2)^+$
$9.14 \pm 0.03 \quad 1^+$	$9.174$				$9.174 \pm 0.015$
					Currently-accepted <sup>e</sup> level energy and $J^\pi$
	$(\alpha, \eta\gamma)^f$	$(\alpha, \alpha)^g$		$(t, {}^3\text{He})^h$	
	$11.745$				$11.75 \pm 0.01$
	$11.751$	$11.76$			$11.76 \pm 0.01 \quad 1^-$
$11.86 \pm 0.08 \quad 2^-$	$11.89$	$11.89$			$11.89 \pm 0.01 \quad 1^-$
					$11.92 \pm 0.01 \quad (2^+)$
		$12.48$			$12.48 \pm 0.01 \quad (2^+)$
$12.56 \pm 0.06 \quad (1^+, 1^-)$	$12.58$				$12.58 \pm 0.01 \quad (1^-)$
		$12.61$			$12.61 \pm 0.01 \quad (1^-, 2^+)$
$15.68 \pm 0.25$			$15.400 \pm 0.040, T=2$		
			$15.610 \pm 0.060, T=2$		

<sup>a</sup>  ${}^{20}\text{Ne}(t, p){}^{22}\text{Ne}$ , Ref. 22.

<sup>b</sup>  ${}^{21}\text{Ne}(d, p){}^{22}\text{Ne}$ , Ref. 24.

<sup>c</sup>  ${}^{18}\text{O}(^7\text{Li}, t){}^{22}\text{Ne}$ , Ref. 25.

<sup>d</sup>  ${}^{23}\text{Na}(t, \alpha){}^{22}\text{Ne}$ , Ref. 23.

<sup>e</sup> Reference 21.

<sup>f</sup>  ${}^{18}\text{O}(\alpha, \eta\gamma){}^{21}\text{Ne}$ , Ref. 27.

<sup>g</sup>  ${}^{18}\text{O}(\alpha, \alpha){}^{18}\text{O}$ , Ref. 28.

<sup>h</sup>  ${}^{22}\text{Ne}(t, {}^3\text{He}){}^{22}\text{F}$ , Ref. 20.

<sup>20</sup>R. H. Stokes and P. G. Young, Phys. Rev. 178, 1769 (1969).

<sup>21</sup>P. M. Endt and C. Van der Leun, Nucl. Phys. A214, 1 (1973), and references therein.

<sup>22</sup>M. G. Silbert and N. Jaramie, Phys. Rev. 123, 221 (1961).

<sup>23</sup>S. Hinds, private communication to Ref. 21.

<sup>24</sup>P. Neogy, R. Middleton, and W. Scholz, Phys. Rev. C 6, 885 (1972).

<sup>25</sup>W. Scholz, P. Neogy, K. Bethge, and R. Middleton, Phys. Rev. C 6, 893 (1972).

<sup>26</sup>W. Kutschera, D. Pelte, and G. Schrieder, Nucl. Phys. A111, 529 (1968).

<sup>27</sup>G. Chouraqui, Th. Muller, M. Port, and J. M. Thirion, J. Phys. (Paris) 31, 249 (1970).

<sup>28</sup>S. Corodetzky, M. Port, J. Graff, J. M. Thirion, and G. Chouraqui, J. Phys. (Paris) 29, 271 (1968).

<sup>12</sup>See, for example, S. J. Skorka, J. Hertel, and T. W. Retz-Schmid, Nucl. Data A 2, 347 (1966).

METHOD

REF. NO.

74 Ve 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR		ANGLE
			TYPE	RANGE	TYPE	
G, 2N *	ABX	18- 26	D	18- 26	BF3-I	4PI

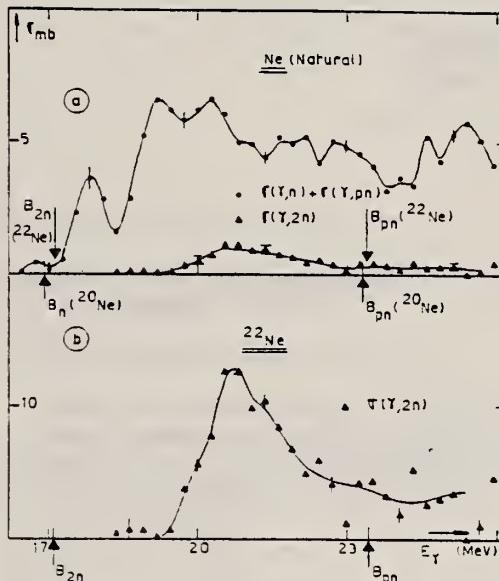


Fig. 4. (a) Photonuclear cross sections  $[\sigma(\gamma, n) - \sigma(\gamma, pn)]$  and  $\sigma(\gamma, 2n)$  for natural Ne. (b) Partial photoneutron cross section  $\sigma(\gamma, 2n)$  of  $^{22}\text{Ne}$ .

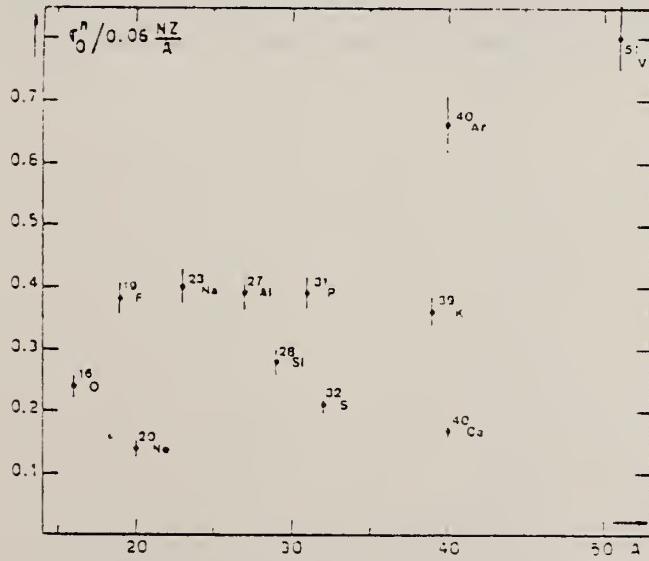


Fig. 22. Ratio of experimental integrated photoneutron cross section  $\sigma_0^n$  over the Thomas, Reichle, and Kuhn sum rule  $[0.06 NZ/A]$ . Numerical values and upper integration limits  $E_M$  are taken from table 3. Also  $\Delta\sigma_0^n = \pm 7\%$  for all nuclei.

(over)

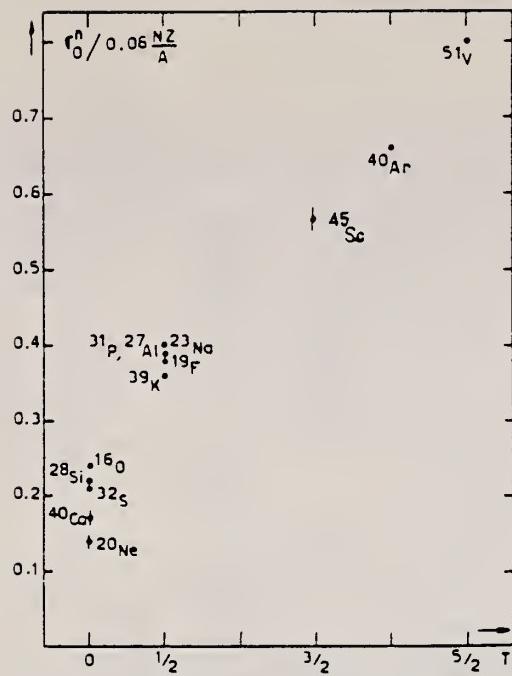


Fig. 24. The  $[\sigma_0^n / (0.06 NZ/A)]$  ratio as a function of isospin  $T$ . Possible overall errors of  $\pm 7\%$  are to be applied to all nuclei shown.

TABLE 3  
Experimental integrated photoneutron cross sections  $\sigma_0^n = \int_0^{E_M} \sigma_{Tn}(E) dE$  compared with the classical sum rule  $[0.06 NZ/A]$  of Thomas, Reich and Kuhn

Nucleus	$T = 0$					$T = \frac{1}{2}$					$T = \frac{1}{2}, T = 2, T = \frac{3}{2}$		
	$^{16}\text{O}$	$^{20}\text{Ne}$	$^{28}\text{Si}$	$^{32}\text{S}$	$^{40}\text{Ca}$	$^{19}\text{F}$	$^{23}\text{Na}$	$^{27}\text{Al}$	$^{31}\text{P}$	$^{39}\text{K}$	$^{45}\text{Sc}$	$^{40}\text{Ar}$	$^{51}\text{V}$
$\sigma_0^n$ (MeV · mb)	58	42	94	98	100	108	137	158	182	210	383	393	602
	$\pm 4$	$\pm 3$	$\pm 7$	$\pm 7$	$\pm 7$	$\pm 7$	$\pm 9$	$\pm 10$	$\pm 12$	$\pm 14$	$\pm 25$	$\pm 28$	$\pm 42$
$\sigma_0^n / (0.06 NZ/A)$	0.24	0.14	0.22	0.21	0.17	0.38	0.40	0.39	0.39	0.36	0.57	0.66	0.8
$E_M$ (MeV)	30	26.7	30	30	29.5	29	30	30	29	30	28.1	26.7	28

REF. X.K. Maruyama, R.A. Lindgren, W.L. Bendel, E.C. Jones, Jr., and  
L.W. Fagg  
Phys. Rev. C 17, 856 (1978)

ELEM. SYM.	A	Z
Ne	22	10

METHOD

REF. NO.

78 Ma 6

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,E/	ABX	0- 19	D	37- 60	MAG-D		180

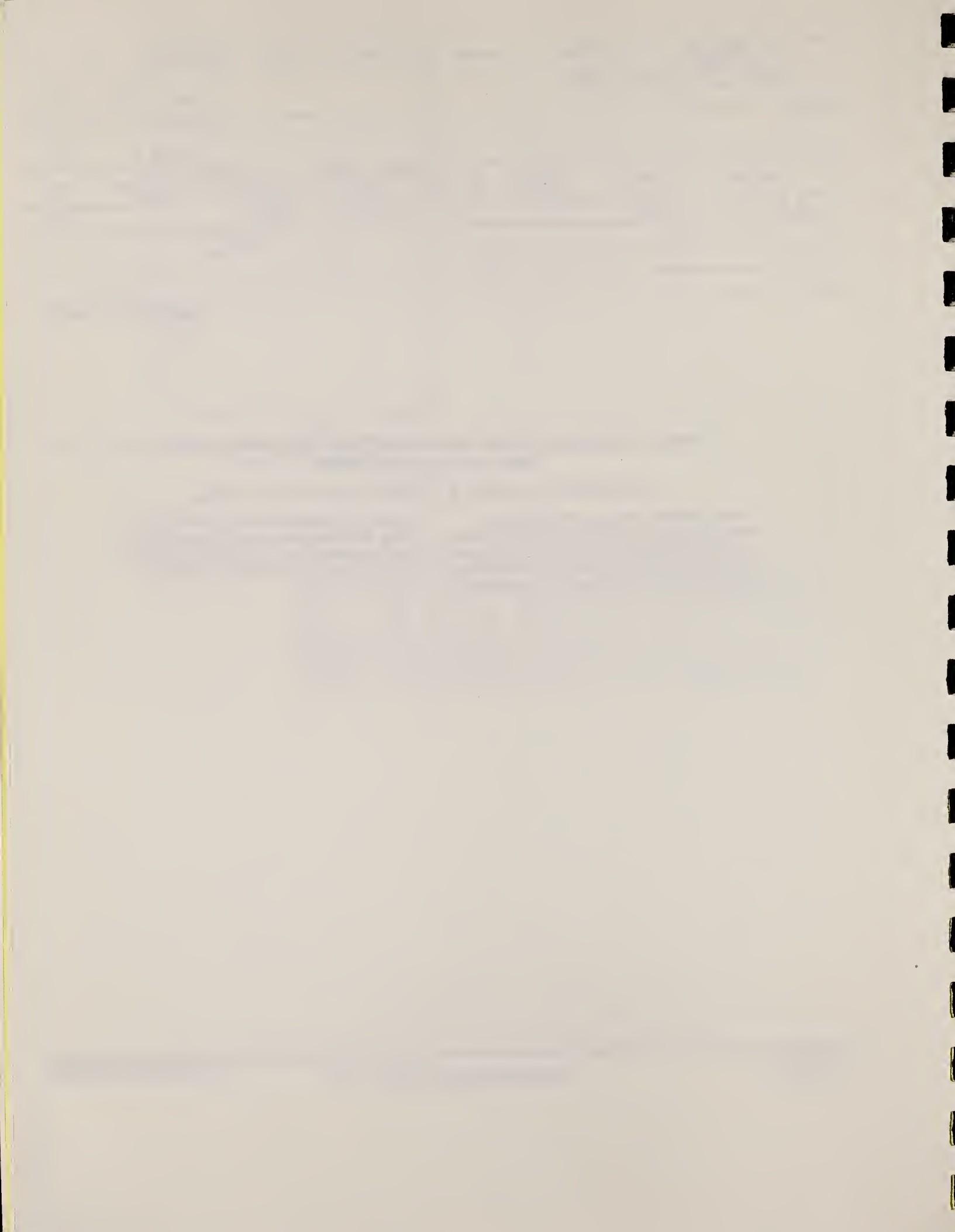
ERRATUM SEE 74Ma8

Erratum: Excitation of  $M_1$  and  $M_2$  states in  $^{22}\text{Ne}$  by  $180^\circ$  electron scattering  
[Phys. Rev. C 10, 2257 (1974)]

X. K. Maruyama, R. A. Lindgren, W. L. Bendel, E. C. Jones, Jr., and L. W. Fagg

Cross sections, reduced matrix elements, electromagnetic widths to the ground state, and transition strengths for  $^{22}\text{Ne}$  deduced from the experimental data should be multiplied by 2. The published results were obtained with a miscalcu-

lation of the relative densities of  $^{22}\text{Ne}$  and  $\text{H}_2$ . On p. 2262, first paragraph, right hand column, last two lines, there is a typographical error;  $2.79\mu_0$  and  $-1.91\mu_0$  should be interchanged.



Ne	22	10
METHOD	REF. NO.	
	78 Tr 3	hmg
REACTION	RESULT	EXCITATION ENERGY
A, G	SPC	10-12 (10.2-11.47)
		D 0-3 (.66-2.20)
		SCD-D

**Abstract:** The  $^{18}\text{O}(\alpha, \gamma)^{22}\text{Ne}$  capture reaction has been studied at  $E_\alpha = 0.6\text{--}2.3$  MeV. The known resonance at  $E_\alpha = 2.20$  MeV has been established and fourteen new resonances have been found in the energy range covered. The  $E_\alpha = 1.16, 1.32, 1.45, 1.53, 1.87, 1.96$  and 2.15 MeV resonances correspond to resonances observed previously in the  $^{18}\text{O}(\alpha, n)^{21}\text{Ne}$  reaction. The  $E_\alpha = 0.77, 1.25$  and 1.27 MeV resonances represent new compound states in  $^{22}\text{Ne}$ . Information on branching ratios,  $a_2$  values and total widths is reported. Transition strength arguments and analyses of  $\gamma$ -ray angular distribution data together with results from previous work resulted in the most likely  $J^\pi$  assignments for the resonances.

10.2, 10.92, 11.47 MEV

The  $E_\alpha = 1.66$  and 1.78 MeV resonances are good candidates for the two  $J^\pi = 8^+$  states predicted at  $E_\alpha \approx 11\text{--}12$  MeV and are probably members of the  $K^\pi = 0^+$  (ground state) and  $K^\pi = 2^+$  rotational bands in  $^{22}\text{Ne}$ .

The investigated energy range of  $E_\alpha$  together with that of previous work corresponds to stellar temperatures of  $T = (0.3\text{--}4.3) \times 10^9$  K. The astrophysical reaction rate determined from these data is compared with predictions based in part on the nuclear optical model. The rate is also compared with that of the competing  $^{18}\text{O}(\alpha, n)^{21}\text{Ne}$  reaction.

E NUCLEAR REACTIONS  $^{18}\text{O}(\alpha, \gamma)$ ,  $E = 0.6\text{--}2.3$  MeV; measured  $E_\alpha$ ,  $E_\gamma$ ,  $I_\gamma$ ,  $I_\gamma(\theta)$ ,  $I_\gamma(E)$ ,  $^{22}\text{Ne}$  deduced resonances, resonance strength,  $\Gamma$ ,  $J^\pi$ ,  $\delta$ ,  $\gamma$ -ray branching ratios, astrophysical reaction rate. Enriched  $^{18}\text{O}$  targets. Ge(Li) detector.

TABLE 2  
 Summary of the angular distribution results for  $^{18}\text{O}(\alpha, \gamma)^{22}\text{Ne}$  resonances

$E_\alpha$ (MeV)	Transition (MeV)	$a_2$ *)	$a_4$ **)
1.45	R → 1.27	0.9 ± 0.3	-0.5 ± 0.5
	1.27 → 0	0.4 ± 0.3	
1.53	R → 0	-1.0 ± 0.3	-0.15 ± 0.13
	R → 1.27	-0.15 ± 0.13	
1.87	1.27 → 0	0.35 ± 0.12	0.3 ± 0.4
	R → 1.27	0.3 ± 0.4	
1.96	R → 8.90	-0.1 ± 0.2	-0.1 ± 0.3
	8.90 → 1.27	0.1 ± 0.3	
2.20	1.27 → 0	-0.1 ± 0.1	1.2 ± 0.4
	R → 3.36	1.2 ± 0.4	
6.34	R → 6.34	0.1 ± 0.4	-0.3 ± 0.4
	6.34 → 3.36	0.8 ± 0.2	
3.36	3.36 → 1.27	0.4 ± 0.2	-0.15 ± 0.11
	1.27 → 0	0.7 ± 0.2	
5.15	R → 0	-1.06 ± 0.11	0.08 ± 0.12
	R → 1.27	-0.28 ± 0.14	
4.46	R → 5.15	-0.14 ± 0.10	-0.3 ± 0.3
	5.15 → 1.27	0.74 ± 0.18	
4.46	4.46 → 1.27	0.20 ± 0.10	-0.03 ± 0.05
	1.27 → 0	0.24 ± 0.02	

\*) Corrected for finite solid angle of the Ge(Li) detector and finite size of the beam spot on the target.

\*\*)  $A_4$  terms are included only in the analyses, if the  $a_2$  term alone could not fit the data ( $\chi^2_{\text{norm}} \geq 1.4$ ). The errors are obtained by variation of the  $a_4$  terms within the statistical errors of the data.

(OVER)

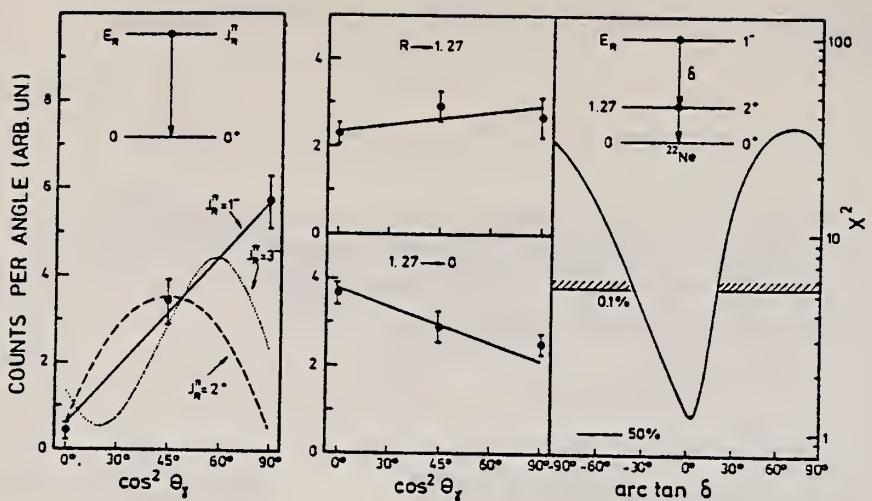


Fig. 6. The  $\gamma$ -ray angular distributions for the  $R \rightarrow 0$  and  $R \rightarrow 1.27 \rightarrow 0$  transitions obtained at the  $E_x = 1.53$  MeV resonance are shown together with their analyses.

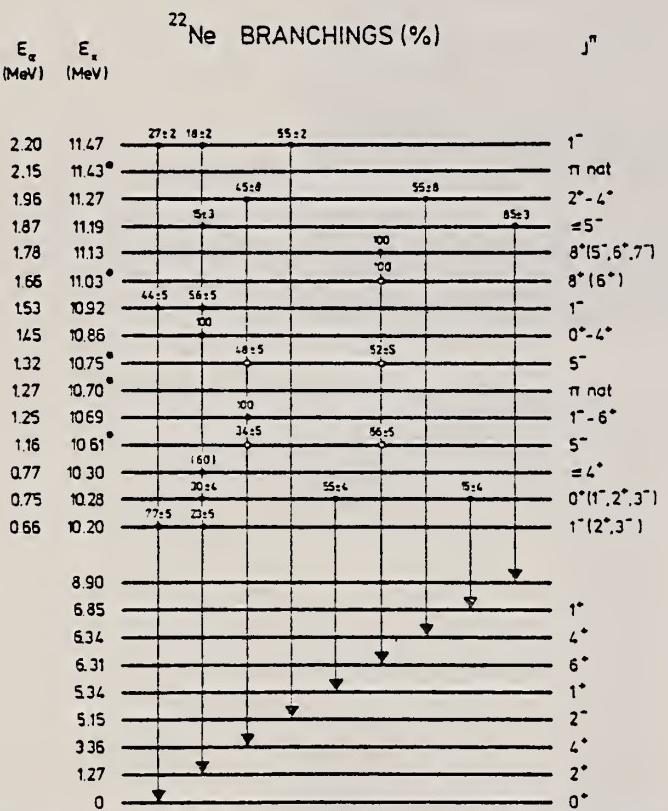


Fig. 7. Summary of results on branching ratios and  $J^\pi$  assignments to states in  $^{22}\text{Ne}$  above the  $\alpha$ -particle threshold. The stars on the  $E_x$  values mark those resonance states, which have been established in the present work only through the 1.27 MeV secondary  $\gamma$ -ray transition. The open circles indicate that the branching ratios for these states are taken from ref. <sup>9</sup>). Information on  $E_x$  and  $J^\pi$  values for the bound states are obtained from refs. <sup>9, 10, 22, 23</sup>.

ELEM. SYM.	A	Z
Ne	22	10

METHOD

REF. NO.

79Be7

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	ABI	5-11 (5.328-10.203)	C	UKN-18	SCD-D		DST

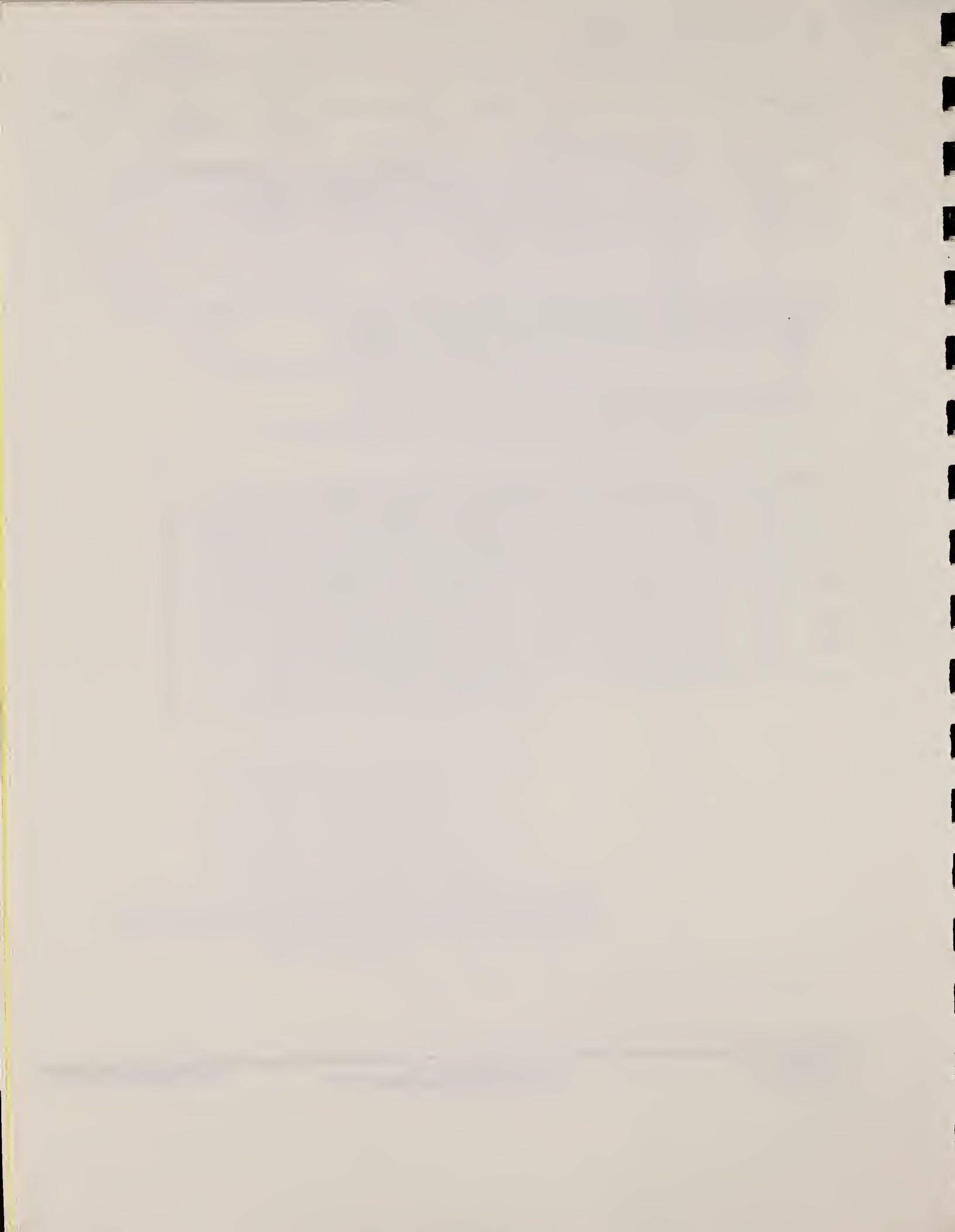
**Abstract:** States at 5.328, 6.851, 8.553, 9.165 and 10.203 MeV in  $^{22}\text{Ne}$  have been observed in a nuclear resonance fluorescence experiment using bremsstrahlung and high resolution Ge(Li) diodes. Photon scattering cross sections,  $\gamma$ -ray decay widths to the ground and first excited states, and lifetimes are derived. The results are compared with inelastic electron scattering data and shell model calculations.

LFT

E NUCLEAR REACTION  $^{22}\text{Ne}(\gamma, \gamma)$ ,  $E < 18$  MeV; measured  $E_\gamma$ ,  $\sigma(\gamma, \gamma)$ ,  $^{22}\text{Ne}$  deduced mean lives,  $\Gamma_{\gamma\gamma}$ ,  $B(\text{M1})$  values. Enriched target.

TABLE I  
Total photon scattering cross sections  $\sigma$ ,  $\gamma$ -ray decay widths  $\Gamma$ , mean lives, and M1 transition probabilities in  $^{22}\text{Ne}$  from resonance fluorescence

$E_\gamma$ at 127° (keV)	Decay mode	$\sigma$ (MeV mb)	$\Gamma_0$ (eV)	$\Gamma_i$ (eV)	$\left( \frac{\Gamma_i}{\Gamma} \right)_s$	Mean lives (fs)	$B(\text{M1}, 1^+ \rightarrow 0^-)$ ( $\mu\text{s}$ )
5328 ± 5	5326 → g.s.	0.10 ± 0.04	0.25 ± 0.10		1	2.6 ± 1.8	0.15 ± 0.06
6851 ± 3	6849 → g.s.	0.32 ± 0.11	1.65 ± 0.65		0.79	0.31 ± 0.15	0.44 ± 0.15
	5576 → 1275	0.085 ± 0.049		0.44 ± 0.28	0.21		
8553 ± 3	8549 → g.s.	0.20 ± 0.08	1.28 ± 0.51		1	0.51 ± 0.34	0.18 ± 0.07
9165 ± 3	9161 → g.s.	0.75 ± 0.25	5.44 ± 1.81		1	0.12 ± 0.06	0.61 ± 0.20
10203 ± 4	10198 → g.s.	0.87 ± 0.29	9.38 ± 3.25		0.84	0.059 ± 0.033	
	8923 → 10203 → 1275	0.17 ± 0.07		1.83 ± 0.78	0.16		



METHOD

REF. NO.

79Ma3

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	FMF	1-9 (1.275-8.59)	D	60-110	MAG-D	51-109	DST

The states of  $^{22}\text{Ne}$  below 8.6 MeV excitation energy have been studied using the technique of inelastic electron scattering. Ratios of inelastic to elastic scattering cross sections were measured with incident electron energies between 60 and 110 MeV and scattering angles of  $110^\circ$  and  $128^\circ$ . Form factors for 14 inelastic transitions were measured for the momentum transfer range 0.4 to  $1.0 \text{ fm}^{-1}$ . Reduced transition probabilities for these states have been deduced and assignments of spin and parity have been made.

14 LEVELS, J-PI, B(CL)

Comparison of  $J^\pi$  results with assignments given in 7 other references is made in Table VIII.

[NUCLEAR REACTIONS  $^{22}\text{Ne}(e, e')$ ,  $E=60$  to  $110$  MeV; measured  $\sigma(E)$  at  $110^\circ$  and  $128^\circ$  up to 8.6 MeV in excitation energy; deduced  $J$ ,  $\pi$ ,  $B(CL)$ . Enriched  $^{22}\text{Ne}$  target.]

TABLE IV. Squared longitudinal form factors,  $F_L^2$  obtained from this experiment. Coulomb correction factors  $f_c$  have been applied to all states. For the state at 6.27 MeV, no Coulomb correction factor was applied.  $F_L^2$  for the states at 6.70, 7.46, 8.17, and 8.59 MeV are tabulated assuming  $J^\pi = 3^-$ ; to compute  $F_L^2$  assuming  $J^\pi = 2^+$  for these states, multiply by the ratio  $f_c(2^+)/f_c(3^-)$  from the values of Table III.

$E_\gamma$ (MeV)	$\theta$ (deg)	$E_\gamma$ (MeV), $J^\pi$ 1.275, $2^+$	$F_L^2 \times 10^3$			
			3.36, $4^+$	4.46, $2^+$	5.91, $3^-$	6.14, $2^+$
59.59	110.39	$4.30 \pm 0.21$	...	$0.215 \pm 0.027$	$0.075 \pm 0.021$	$0.083 \pm 0.020$
59.59	110.39	$4.35 \pm 0.26$	...	$0.204 \pm 0.015$	$0.080 \pm 0.013$	$0.047 \pm 0.014$
59.59	110.39	$4.57 \pm 0.20$	...	$0.232 \pm 0.019$	$0.070 \pm 0.023$	$0.051 \pm 0.012$
69.69	110.45	$6.56 \pm 0.28$	...	$0.304 \pm 0.020$	$0.163 \pm 0.013$	...
69.91	110.39	$7.68 \pm 0.32$	...	$0.309 \pm 0.025$	$0.157 \pm 0.019$	$0.078 \pm 0.023$
85.13	110.36	$9.39 \pm 0.42$	$0.004 \pm 0.011$	$0.430 \pm 0.024$	$0.337 \pm 0.021$	$0.098 \pm 0.015$
100.34	110.36	$11.51 \pm 0.49$	$0.163 \pm 0.012$	$0.462 \pm 0.026$	$0.736 \pm 0.035$	$0.134 \pm 0.021$
110.61	110.29	$10.86 \pm 0.46$	$0.229 \pm 0.075$	$0.496 \pm 0.028$	$0.974 \pm 0.045$	$0.139 \pm 0.023$
63.34	128.16	$6.48 \pm 0.33$	...	$0.257 \pm 0.023$	...	...
77.42	128.17	$9.39 \pm 0.39$	$0.045 \pm 0.026$	$0.386 \pm 0.029$	$0.362 \pm 0.020$	$0.115 \pm 0.015$
110.56	128.05	$10.34 \pm 0.57$	$0.386 \pm 0.045$	$0.461 \pm 0.040$	$1.377 \pm 0.075$	$0.151 \pm 0.031$
$E_\gamma$ (MeV), $J^\pi$ 6.27, $0^+$		$6.70, (3^-, 2^+)$	$6.90, 1^-$	$7.06, 2^+$	$7.46, (3^-, 2^+)$	
59.59	110.39	$0.089 \pm 0.022$	$0.090 \pm 0.021$	$0.156 \pm 0.030$	...	...
59.59	110.39	$0.087 \pm 0.016$	$0.082 \pm 0.013$	$0.130 \pm 0.020$	...	...
59.59	110.39	$0.083 \pm 0.019$	$0.055 \pm 0.014$	$0.103 \pm 0.025$	$0.052 \pm 0.016$	...
69.91	110.39	$0.102 \pm 0.026$	$0.121 \pm 0.013$	$0.175 \pm 0.028$	$0.068 \pm 0.019$	$0.052 \pm 0.010$
85.13	110.36	$0.097 \pm 0.016$	$0.150 \pm 0.013$	$0.164 \pm 0.021$	$0.072 \pm 0.011$	$0.116 \pm 0.012$
100.34	110.36	$0.138 \pm 0.020$	$0.319 \pm 0.021$	$0.152 \pm 0.037$	$0.120 \pm 0.016$	$0.206 \pm 0.017$
110.61	110.29	$0.156 \pm 0.021$	$0.344 \pm 0.024$	$0.053 \pm 0.042$	$0.115 \pm 0.021$	$0.271 \pm 0.021$
77.42	128.17	$0.133 \pm 0.015$	$0.207 \pm 0.015$	$0.165 \pm 0.043$	$0.079 \pm 0.010$	$0.121 \pm 0.011$
110.56	128.05	$0.170 \pm 0.023$	$0.451 \pm 0.032$	$0.031 \pm 0.073$	$0.120 \pm 0.034$	$0.308 \pm 0.028$
$E_\gamma$ (MeV), $J^\pi$ 7.65, $2^+$		$7.93, 2^+$	$8.17, (3^-, 2^+)$	$8.59, (3^-, 2^+)$		
59.59	110.39	$0.292 \pm 0.025$	$0.072 \pm 0.013$	$0.021 \pm 0.012$	$0.131 \pm 0.012$	
69.91	110.39	$0.487 \pm 0.030$	$0.127 \pm 0.019$	...	$0.235 \pm 0.021$	
85.13	110.36	$0.762 \pm 0.038$	$0.195 \pm 0.014$	$0.074 \pm 0.012$	$0.371 \pm 0.034$	
100.34	110.36	$0.921 \pm 0.049$	$0.213 \pm 0.019$	$0.075 \pm 0.016$	$0.557 \pm 0.034$	
110.61	110.29	$1.207 \pm 0.053$	$0.201 \pm 0.021$	$0.113 \pm 0.019$	$0.653 \pm 0.037$	
77.42	128.17	$0.731 \pm 0.045$	$0.179 \pm 0.019$	$0.063 \pm 0.014$	$0.396 \pm 0.042$	
110.56	128.05	$1.122 \pm 0.073$	$0.151 \pm 0.025$	$0.126 \pm 0.023$	$0.917 \pm 0.064$	

(continued)

TABLE VI. Excitation energies and reduced transition probabilities. The energies of states from the literature identified with the experimentally observed states are presented along with the assumed  $J^\pi$  and deduced  $B(CL)^\dagger$ . The  $B(CL)^\dagger$  are averages of those in Table V. The uncertainties associated with  $B(CL)^\dagger$  reflect the range of values including fitting errors allowed by the models considered. Where fewer than four of the models considered allowed a satisfactory fit, the uncertainties are not presented. The reduced transition probabilities for those states are to be considered approximate values.

No.	$E_i$ (lit.) (keV)	$E_i$ (expt.) (MeV)	$J^\pi$	$B(CL)^\dagger$ ( $e^2 \text{ fm}^2 L$ )
1	1274.57 $\pm$ 0.02	1.275 $\pm$ 0.010	2 <sup>+</sup>	271 $\pm$ 36
2	3357.2 $\pm$ 0.4	3.36 $\pm$ 0.02	4 <sup>-</sup>	17000 $\pm$ 4000
3	4456.7 $\pm$ 1.6	4.46 $\pm$ 0.02	2 <sup>+</sup>	13 $\pm$ 2
9	5909.9 $\pm$ 1.8	5.91 $\pm$ 0.02	3 <sup>-</sup>	870 $\pm$ 250
10	6115 $\pm$ 6	6.14 $\pm$ 0.04	2 <sup>+</sup>	3.2 $\pm$ 1.5
11	6237 $\pm$ 5	6.27 $\pm$ 0.05	0 <sup>-</sup>	3.8 $\pm$ 1.1
15	6691 $\pm$ 4	6.70 $\pm$ 0.02	2 <sup>+</sup>	3.9 $\pm$ 1.5
			3 <sup>-</sup>	750 $\pm$ 400
18	6904 $\pm$ 1.6	6.90 $\pm$ 0.03	1 <sup>-</sup>	0.08 $\pm$ 0.04
19	7052 $\pm$ 7	7.06 $\pm$ 0.03	2 <sup>+</sup>	2.1 $\pm$ 1.2
25	7470 $\pm$ 20	7.46 $\pm$ 0.03	2 <sup>+</sup>	1.6
			3 <sup>-</sup>	350 $\pm$ 250
29	7644 $\pm$ 4	7.65 $\pm$ 0.02	2 <sup>+</sup>	18 $\pm$ 3
32	7924 $\pm$ 6	7.93 $\pm$ 0.02	2 <sup>+</sup>	5.7 $\pm$ 2.4
35	8162 $\pm$ 4	8.17 $\pm$ 0.02	2 <sup>+</sup>	1.3 $\pm$ 1.3
			3 <sup>-</sup>	270 $\pm$ 270
41	8393 $\pm$ 7	8.59 $\pm$ 0.02	2 <sup>+</sup>	7
			3 <sup>-</sup>	1700

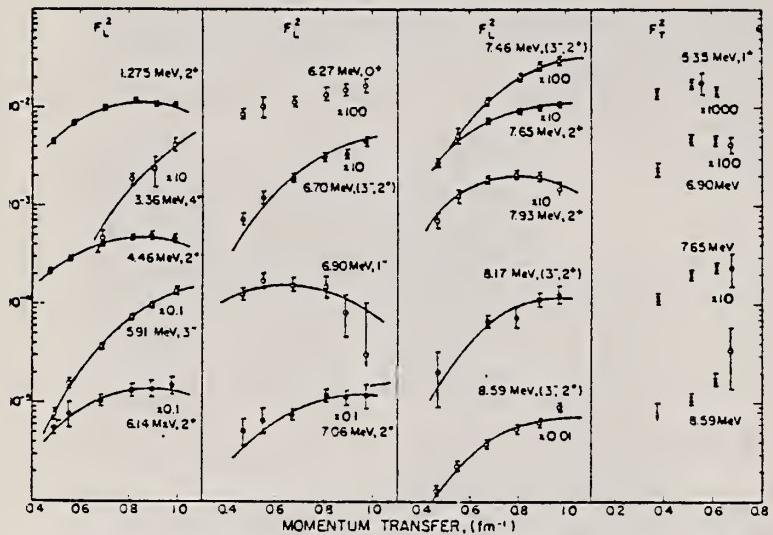
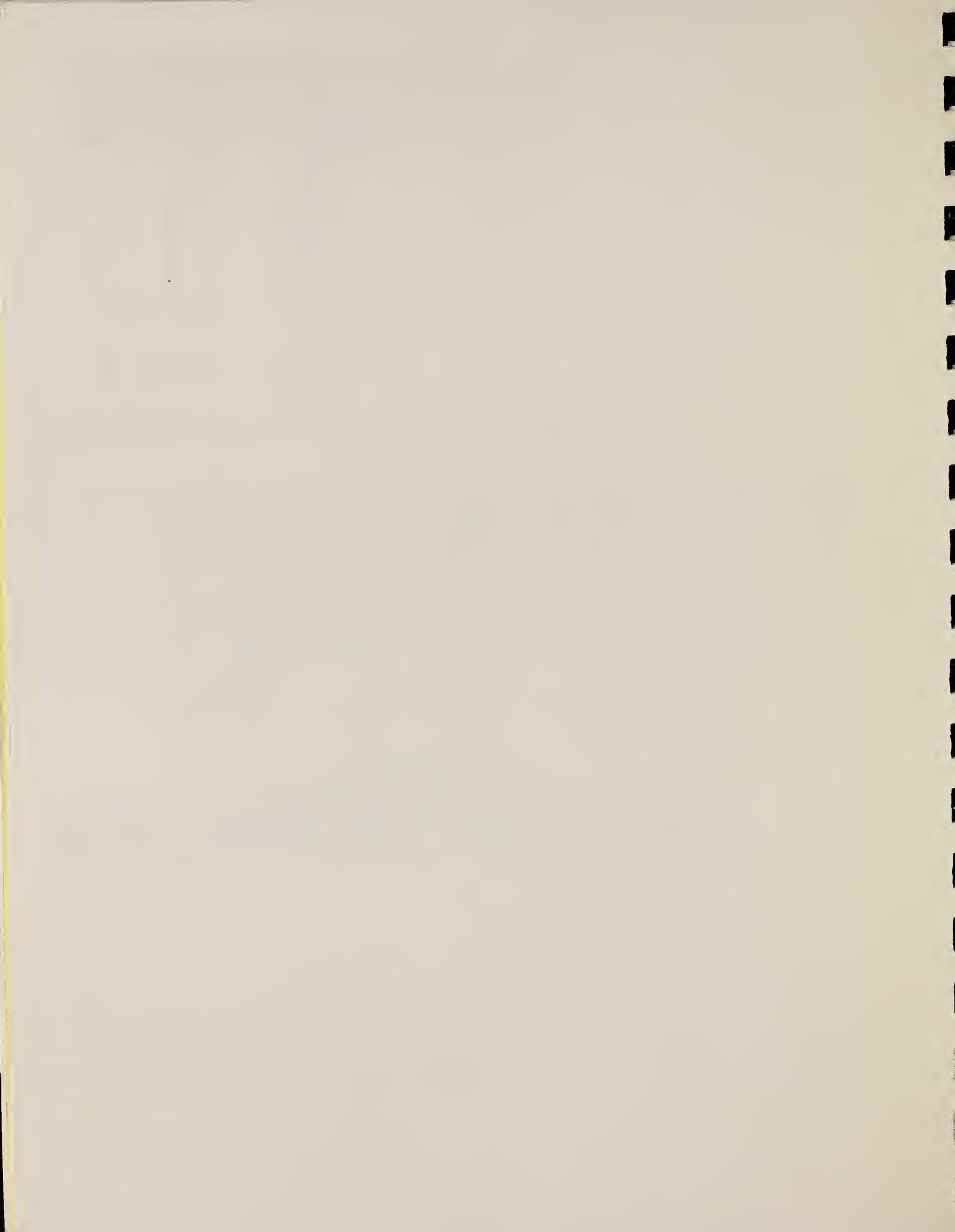


FIG. 2. Born approximation form factors for states observed in this experiment.  $F_L^2$  for all states except at 6.27 MeV are the longitudinal squared form factors with Coulomb distortion corrections  $f_c$  applied.  $F_T^2$  are the transverse squared form factors without Coulomb distortion corrections. The circles are measurements obtained in this experiment. Open and closed circles are used to aid in distinguishing among the various states. The solid line through the data are fits obtained using the generalized Helm model (model 4 of Table V). The crosses represent the 180° electron scattering data of Ref. 8.





SODIUM  
Z=11

Sir Humphry Davy isolated sodium in the fall of 1807 and announced its discovery before the Royal Society in London in November of that year. He did electrolysis of sodium hydroxide to obtain the metal. The following year, Joseph Gay-Lussac (1778-1850) and Louis Thénard used a chemical process to reduce sodium hydroxide by iron at a high temperature. These two methods for sodium production produced a conflict that raged for over a century and was not resolved until the introduction of the Downs process in 1921 which made sodium the cheapest non-ferrous metal available. The incentive for all this activity was provided by Hans Christian Oersted's (1777-1851) discovery that sodium could be used to prepare pure aluminum by the reduction of aluminum chloride.



Elem. Sym.	A	Z
Na	21	11
Ref. No. 61 Be 2		JHH

Method Van de Graaff; NaI

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
(p, $\gamma$ )	1.17	$3.61 \pm 0.06$				

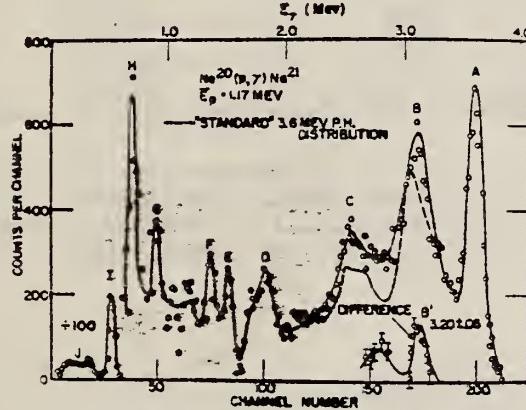


FIG. 7. Single 3X3 NaI crystal spectrum of gamma rays following capture of 1.17-Mev protons by Ne<sup>20</sup>.

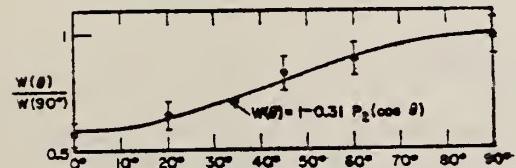


FIG. 8. Angular distribution of gamma rays corresponding to peak A of Fig. 7.

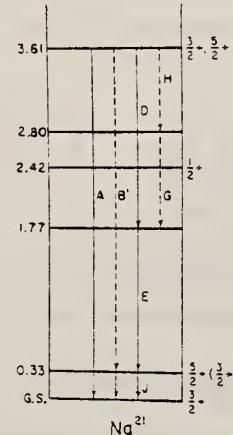


FIG. 11. Energy-level scheme of Na<sup>21</sup> from present work. Gamma-ray transitions are labeled by peaks in Fig. 7. Dashed lines indicate transitions based purely on energy differences with no further supporting evidence.

METHOD				REF. NO.	
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE	RANGE	
P, G	LFT	8-10	D	6-8 (6.850-7.215)	SCD-D 0-9
					90

8.973, 9.216 MEV

The  $\gamma$  decays of the two lowest  $T = \frac{3}{2}$  states in Na<sup>21</sup> at 8.97 and 9.22 MeV were studied as resonances in the Ne<sup>20</sup>(p,  $\gamma$ ) reaction by use of a gas cell and a 30-cc Ge(Li) detector. For the lower resonance, we find three branches: to the  $\frac{1}{2}^+$  ground state (11%), to the  $\frac{3}{2}^+$  first excited state (50%), and to the  $\frac{5}{2}^+$  second excited state (39%). These results imply that  $J = \frac{3}{2}^+$  for the  $T = \frac{3}{2}$  state. On the simple rotational model, transitions from states of the  $K = \frac{1}{2}$  (Nilsson orbit #6) band are possible only to the ground-state  $K = \frac{1}{2}$  (#7) band. A  $J = \frac{3}{2}^+$ ,  $K = \frac{1}{2}$  assignment for the lowest  $T = \frac{3}{2}$  state fits the observed branching ratios. The second resonance decays predominantly to the ground state, and there is at most a 9% branch to the  $\frac{1}{2}^+$  state at 2.41 MeV. The second resonance is assigned  $J = \frac{3}{2}^+$ ,  $K = \frac{1}{2}$ . If the 2.41-MeV state is  $K = \frac{1}{2}$  (#9), no transition to it is expected. On both resonances, transitions to higher excited states are obscured by background.

TABLE I. Radiative widths for the various observed transitions. In calculating the widths for the decay of the 8.973-MeV state, the proton branching ratio estimated from the work of Hardy and Bell<sup>a</sup> has been used; for the 9.216-MeV state,<sup>b</sup> the branching ratio given by McDonald *et al.*<sup>b</sup> has been used.

$E_i(T = \frac{3}{2}) \rightarrow E_f(T = \frac{3}{2})$	$J_i^{\pi} \rightarrow J_f^{\pi}$	$(2J, +1)$ $(\Gamma_p \Gamma_{\gamma} / \Gamma)$ (eV)	$\Gamma_{\gamma}$ (eV)	$ M_{M1} ^2$
8.973-0	$\frac{3}{2}^+ \rightarrow \frac{1}{2}^+$	1.1	$0.73 \pm 0.3$	$0.06 \pm 0.03$
8.973-0.338	$\frac{3}{2}^+ \rightarrow \frac{3}{2}^+$	5.1	$3.3 \pm 0.6$	$0.31 \pm 0.06$
8.973-1.72	$\frac{3}{2}^+ \rightarrow \frac{5}{2}^+$	4.1	$2.7 \pm 0.5$	$0.39 \pm 0.08$
9.216-0	$\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$	8.7	$9.5 \pm 1.9$	$0.68 \pm 0.13$
9.216-2.41	$\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$	<0.8	<0.9	<0.17

<sup>a</sup> Reference 8.

<sup>b</sup> Reference 7.

- <sup>a</sup> J. C. Hardy and R. E. Bell, Can. J. Phys. 43, 1671 (1965).  
<sup>b</sup> A. B. McDonald, J. R. Patterson, and H. Winkler, Bull. Am. Phys. Soc. 13, 652 (1968); and (to be published).

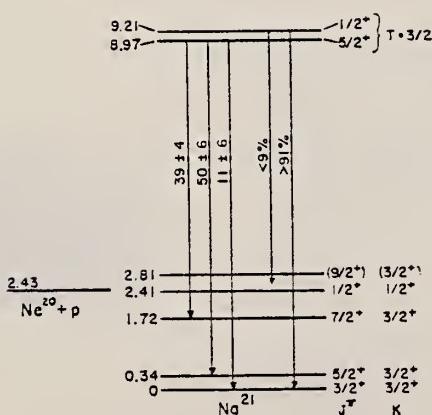


FIG. 3.  $\gamma$ -ray branching ratios for the two lowest  $T = \frac{3}{2}$  states in Na<sup>21</sup>. In computing the branching ratios, the angular distributions have been assumed to be those for pure  $M1$  transitions.

ELEM. SYM.	A	Z
Na	21	11
REF. NO.	74 Ro 4	egf

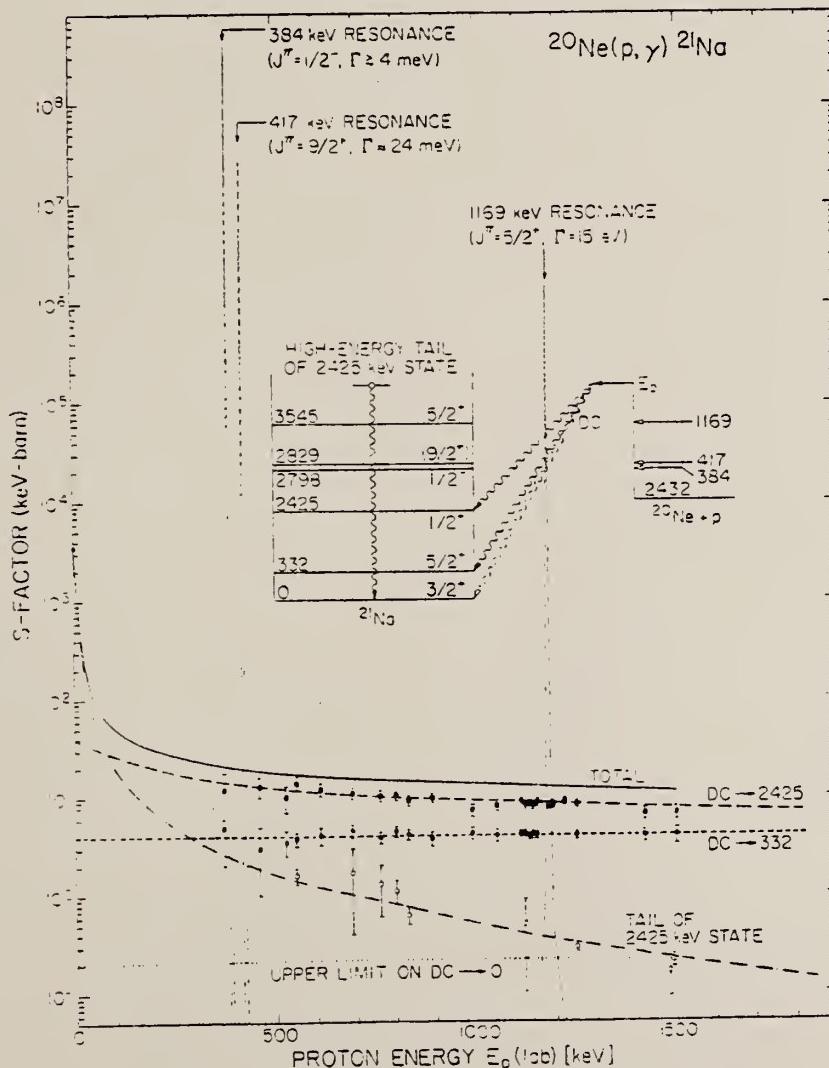
METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE	RANGE	
P.G	ABX	2- 3	D	1- 2	SCD-D

The high-energy tail of the  $J^\pi = 1/2^+$ , 2425 keV state in  $^{21}\text{Na}$ , bound by 7 keV against proton decay, has been observed in the  $^{20}\text{Ne}(p, \gamma)^{21}\text{Na}$  reaction at  $E_p = 0.5 - 1.5$  MeV. The observed excitation function is consistent with a single-level Breit-Wigner shape with  $\Gamma_\gamma = 0.31 \pm 0.07$  eV at  $E_\gamma = 2425$  keV.

$$S(E) = \sigma(E) E_{\text{cm}} \exp(2\eta)$$

$\eta$  = Coulomb parameter



- 2 C. Rolfs et al.  
to be published.  
3 P.M. Endt and C.  
Van der Leun, Nucl.  
Phys. A214 (1973) 1.

Fig. 2. Astrophysical S-factor for the  $^{20}\text{Ne}(p, \gamma)^{21}\text{Na}$  reaction. The dashed lines through the DC  $\rightarrow 332$  and DC  $\rightarrow 2425$  keV data points taken from ref. [2] are model predictions. The dashed-dotted line is the theoretical prediction of the high-energy tail of the 2425 keV bound state. A possible DC process to the ground state would have almost the same energy dependence as the DC  $\rightarrow 332$  keV transition and is indicated as a dotted line. Shown also for comparison are the S-factor curves for the  $J^\pi = (5/2)^+$ , 1169 keV resonance [3] and for the new low-energy resonances at  $E_p(J^\pi) = 384(1/2^+)$  and  $417(9/2^+)$  keV, observed in ref. [2].



N<sub>A</sub>  
A=22

N<sub>A</sub>  
A=22

N<sub>A</sub>  
A=22



Elem. Sym.	A	Z
Na	22	11

Method

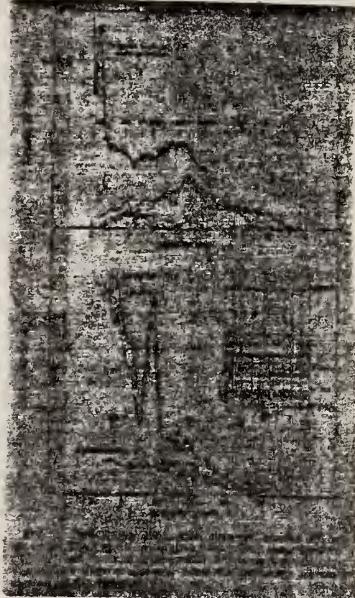
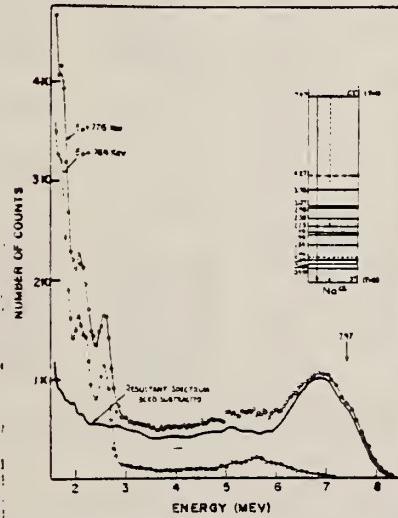
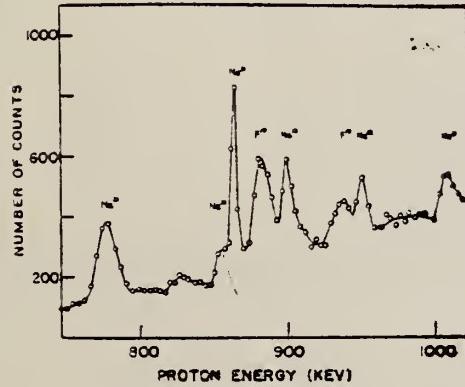
Proton capture; NaI detector

Ref. No.

60 Kr 1

JH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
(p, $\gamma$ )	$E_p = 0.6-1.5 \text{ MeV}$					$^{22}\text{Na} \gamma$ mostly to ground state. $^{22}\text{Na} \gamma$ mostly to 2.25 MeV level.



METHOD					REF. NO.		
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P, G	No X	7	D	0-1	NAI-D	0-8	90
		(7.5 ± 0.1)		.3-1.0			
		(7.23 ± 0.1)					

Resonances in excitation function at  $E_p = 520 \pm 5$  keV and 766 keV      LEVELS, SPIN-PARITY

766 level as  $2^-$       at  $E_Y = 7240 \pm 10$  kev and  $7474 \pm 5$  keV

520 level has small g.s. width

ELEM. SYM.	A	Z
Na	22	11

METHOD

REF. NO.

78 He 3

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P, G	LFT	7-9	D	0-2	SCD-D		DST
		(7.47-8.50)			(.768-1.840)		

Angular distribution measurements of gamma-rays from unbound  $T = 1$  states in  $^{22}\text{Na}$ . R. Hentelä and J. Keinonen (Department of Physics, University of Helsinki, Helsinki, Finland).

Physica Scripta (Sweden) 17, 421-424, 1978.

J-PI

Angular distributions have been measured at six  $^{21}\text{Ne}(p, \gamma)^{22}\text{Na}$  analogue resonances, with  $E_p = 0.70, 0.77, 1.09, 1.21, 1.56$  and  $1.84\text{ MeV}$ , and at a candidate for analogue resonance with  $E_p = 1.11\text{ MeV}$ . Gamma-ray mixing ratios have been obtained for the first time for the decays of these levels with determination of spin-parity assignments. The spins and parities for the bound states at  $1.98$  and  $4.36\text{ MeV}$  have been deduced. Transition strengths provide information on the isoscalar and isovector strengths in the self-conjugated nucleus  $^{22}\text{Na}$ .

Table I. Results of the angular distribution measurements, spins and parities of the resonance states, the experimental angular distribution coefficients corrected for finite solid angle,  $\chi^2$ -values and channel spin ( $\tau$ ) and  $\gamma$ -ray ( $\delta$ ) mixing ratios. Except when otherwise indicated, the energy and final state spin values are as given in ref. [4].

$E_p$ (keV)	$E_i$ (keV)	$E_f$ (keV)	$J_p^\pi$	$J_f^\pi$	$A_2$	$A_4$	$\chi^2$	$\tau$	$\delta$
702	7411	583	1 <sup>+</sup>	1 <sup>+</sup>	0.00 ± 0.04	+ 0.01 ± 0.04	3.3	0.3	+ 0.19 ± 0.10
		1937		1 <sup>+</sup>	+ 0.02 ± 0.03	- 0.01 ± 0.03	5.5	0.3	+ 0.29 ± 0.11
		3060		2 <sup>+</sup>	+ 0.03 ± 0.04	- 0.03 ± 0.04	3.2	0.3	- 0.3 ± 0.3
		3944		1 <sup>+</sup>	+ 0.06 ± 0.03	+ 0.02 ± 0.03	5.0	0.3	+ 1.3 ± 0.9
		4360		1 <sup>-d</sup>	+ 0.06 ± 0.02	- 0.02 ± 0.01	4.5	0.3	+ 0.4 ± 0.4
768	7474	0	2 <sup>+</sup>	3 <sup>+</sup>	+ 0.005 ± 0.009	- 0.02 ± 0.01	9.8	16	+ 0.2 ± 0.2
		1937		1 <sup>+</sup>	+ 0.02 ± 0.02	- 0.01 ± 0.02	3.0	16	- 0.2 ± 0.2
1089	7780	1937 <sup>b</sup>	(1, 2) <sup>-</sup>	1 <sup>+</sup>	- 0.12 ± 0.04	- 0.05 ± 0.04	5.0	1.6	+ 0.05 ± 0.10 (1 <sup>-</sup> )
							5.5	1.6	- 0.1 ± 0.3 (2 <sup>-</sup> )
		2211		1 <sup>-</sup>	- 0.14 ± 0.03	- 0.02 ± 0.03	4.0	1.6	+ 0.03 ± 0.03 (1 <sup>-</sup> )
							4.5	1.6	+ 0.01 ± 0.06 (2 <sup>-</sup> )
1113	7803	0	2 <sup>+(1^+)</sup>	3 <sup>+</sup>	+ 0.01 ± 0.05	- 0.03 ± 0.05	3.0	6	> - 0.35
		1952		2 <sup>+</sup>	+ 0.03 ± 0.03	- 0.04 ± 0.03	(3.3)	(0.4)	(isotropic)
							6.0	6	+ 0.15 ± 0.09
1205	7891	891	4 <sup>+</sup>	4 <sup>+</sup>	+ 0.40 ± 0.02	- 0.01 ± 0.02	1.3	300	- 0.01 ± 0.02
		1528		5 <sup>+</sup>	- 0.09 ± 0.03	- 0.01 ± 0.03	2.6	300	+ 0.03 ± 0.02
		1983		3 <sup>a,c</sup>	- 0.14 ± 0.05	- 0.07 ± 0.05	6.4	300	- 0.08 ± 0.03
1564	8234	0	2 <sup>+</sup>	3 <sup>+</sup>	0.00 ± 0.04	0.00 ± 0.04	2.1	∞	isotropic
		583		1 <sup>+</sup>	+ 0.02 ± 0.05	+ 0.03 ± 0.05	3.6	∞	isotropic
1840 <sup>b</sup>	8495 <sup>b</sup>	0	(1, 2) <sup>*</sup>	3 <sup>+</sup>	+ 0.04 ± 0.03	+ 0.04 ± 0.03	6.7	0	isotropic
							6.7	∞	isotropic

<sup>a</sup> Present work (see text). <sup>b</sup> Ref. [9]. <sup>c</sup> Ref. [12].

(over)

Table II. Electromagnetic transition strengths in  $^{22}\text{Na}$ . Except when otherwise indicated, the branching ratios are taken from ref. [4]. The  $\gamma$ -ray widths  $\Gamma_\gamma$  are from ref. [3].

$E_i$ (MeV)	$E_f$ (MeV)	$J_i^\pi(T_i)$	$J_f^\pi(T_f)$	Branching ratio (%)	$\delta$	$\Gamma_\gamma$ (eV)	Multipolarity	$\Gamma_\gamma/\Gamma_w$ (W.u.)(n) <sup>a</sup>
7.41	0.58	1 <sup>+</sup> (1)	1 <sup>+(0)</sup>	8 ± 1	+ 0.19 ± 0.10	0.20 ± 0.04	M1	(2.9 ± 0.7) (-2)
	1.94		1 <sup>+(0)</sup>	15 ± 2	+ 0.29 ± 0.11	0.33 ± 0.07	M1	(0.9 ± 0.2) (-1)
	3.06		2 <sup>+(0)</sup>	28 ± 2	- 0.3 ± 0.3	0.70 ± 0.14	M1	(3.7 ± 1.0) (-1)
	3.94		1 <sup>+(0)</sup>	18 ± 2	+ 1.3 ± 0.9	0.45 ± 0.09	M1	> 3.5 (1)
	4.36		1 <sup>+(0)</sup>	31 ± 2	+ 0.4 ± 0.4 - 0.1	0.75 ± 0.15	M1	(1.1 ± 0.3) (+ 0.1) (0)
	7.47	0	2 <sup>+(1)</sup>	3 <sup>+(0)</sup>	78 ± 3	+ 0.2 ± 0.2	5.3 ± 1.1	M1
7.78	1.94		1 <sup>+(0)</sup>	10 ± 2	- 0.2 ± 0.2	0.7 ± 0.1	M1	(1.9 ± 0.3) (-1)
	1.94	(1, 2) <sup>-(1)</sup>	1 <sup>+(0)</sup>	28 ± 3 <sup>b</sup>	+ 0.05 ± 0.10 - 0.1 ± 0.3	0.17 ± 0.03 0.10 ± 0.02	E1 E1	(1.6 ± 0.3) (-3) (0.9 ± 0.2) (-3)
	2.21		1 <sup>-(0)</sup>	60 ± 3 <sup>b</sup>	+ 0.03 ± 0.03 + 0.01 ± 0.06	0.40 ± 0.08 0.24 ± 0.05	M1 M1	(1.1 ± 0.2) (-1) (0.7 ± 0.1) (-1)
	7.80	0	2 <sup>+(1*)</sup> (0)	3 <sup>+(0)</sup>	15 ± 2 (isotropic)	> - 0.35 (- 0.2 ± 0.2)	0.18 ± 0.05 0.81 ± 0.16	M1 M1 (E2)
7.89	0.89	4 <sup>+(1)</sup>	4 <sup>+(0)</sup>	34 ± 3	- 0.01 ± 0.02	0.51 <sup>d</sup>	M1	7(-2)
	1.53		5 <sup>+(0)</sup>	48 ± 3	+ 0.03 ± 0.02	0.72 <sup>d</sup>	M1	1.4(-1)
	1.98		3 <sup>+(0)</sup>	14 ± 2	- 0.08 ± 0.03	0.21	M1	5(-2)
	8.23	0	2 <sup>+(1)</sup>	3 <sup>+(0)</sup>	55 ± 3	isotropic	1.2 ± 0.2	M1
8.50	0.58		1 <sup>+(0)</sup>	12 ± 2	isotropic	0.26 ± 0.06	M1	(2.8 ± 0.6) (-2)
	0	2 <sup>+(1)</sup>	3 <sup>+(0)</sup>	97 ± 5 <sup>b</sup>	isotropic	5.2 ± 1.4	M1	(4.1 ± 1.1) (-1)
		1 <sup>+(0)</sup>			isotropic		E2	(4.0 ± 1.1) (+ 1)

<sup>a</sup> (n) means  $\times 10^n$ . <sup>b</sup> Ref. [9]. <sup>c</sup> Calculated for the pure transition. <sup>d</sup> Estimated from ref. [3].

NA  
A=23

NA  
A=23



METHOD

REF. NO.

Linac; counted delayed neutrons from N<sup>17</sup>

55 Re 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N17	ABI	THR - 400	C	90-400	ACT-I		4PI

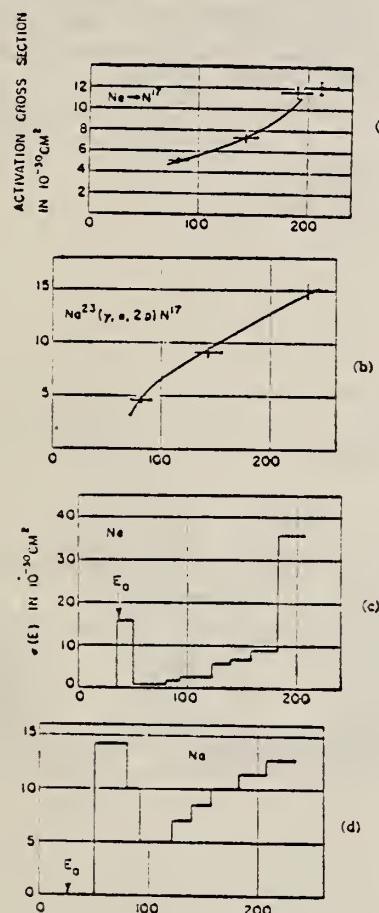


FIG. 4. Experimental N<sup>17</sup> activation points for neon and sodium are plotted in the upper graphs. The lower graphs are the photon cross sections, which were calculated as indicated in the text. The activation cross sections indicated by the solid lines are reconstructions from the photon cross sections shown. The photon cross sections for energies below 80 Mev were chosen arbitrarily.

Elem. Sym.	A	Z
Na	23	11

Method Betatron; photon scattering; NaI spectrometer

Ref. No.  
56 Fu 1

NVB

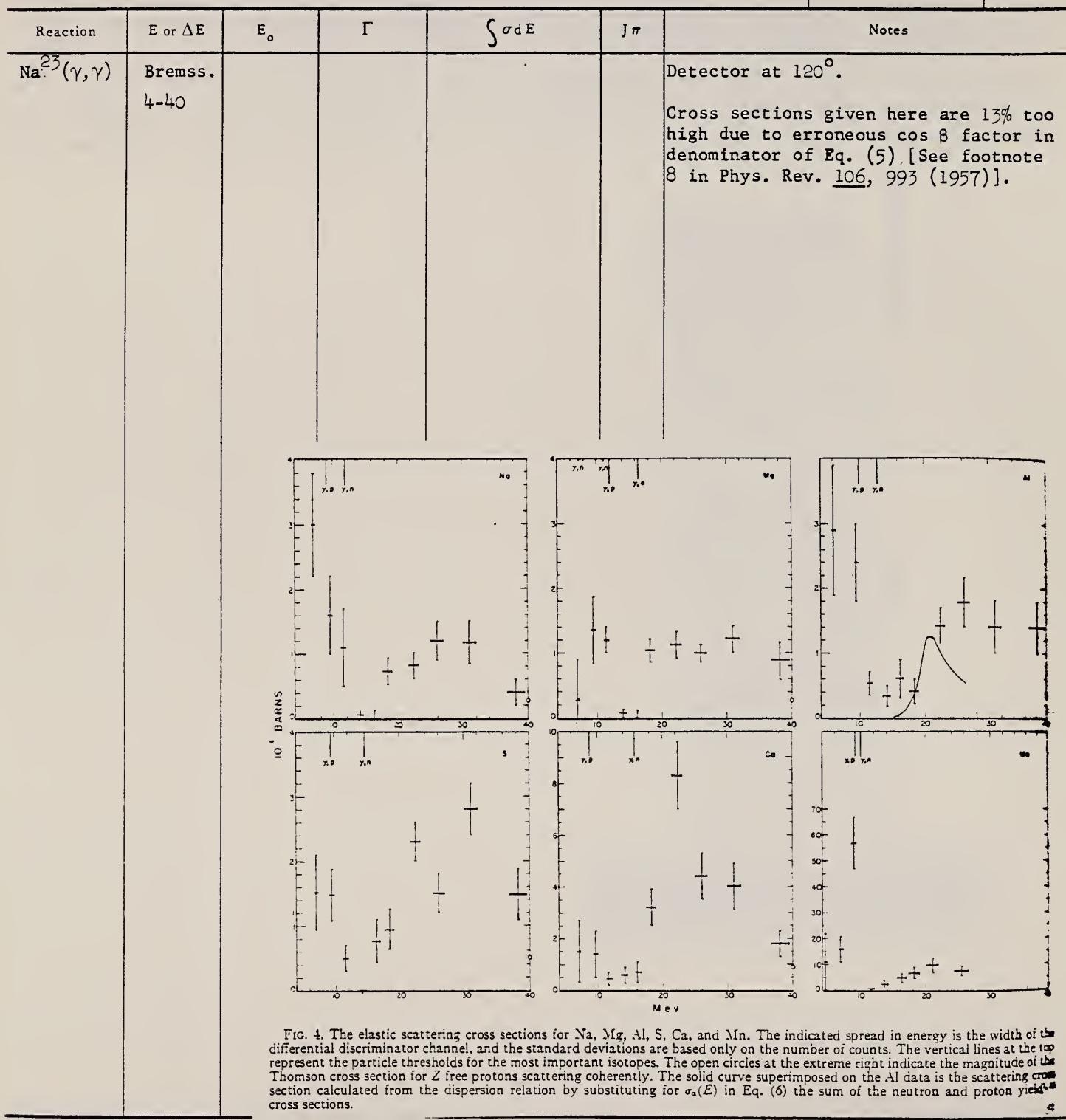


FIG. 4. The elastic scattering cross sections for Na, Mg, Al, S, Ca, and Mn. The indicated spread in energy is the width of the differential discriminator channel, and the standard deviations are based only on the number of counts. The vertical lines at the top represent the particle thresholds for the most important isotopes. The open circles at the extreme right indicate the magnitude of the Thomson cross section for  $Z$  free protons scattering coherently. The solid curve superimposed on the Al data is the scattering cross section calculated from the dispersion relation by substituting for  $\sigma_n(E)$  in Eq. (6) the sum of the neutron and proton yield cross sections.

METHOD  
 Betatron

REF. NO.  
 58 Ch 2 NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N	RLY	THR	C	THR	BF <sub>3</sub> -I		4PI

TABLE I  
 MEASURED PHOTONEUTRON THRESHOLDS

THRESHOLD

Reaction	Measured Q value, Mev.	Other Q values, Mev.	Method	Reference
Na <sup>22</sup> (γ, n)Na <sup>21</sup>	12.47 ± 0.05 (12.46 ± 0.08)	12.05 ± 0.20 12.42 ± 0.05 12.417 ± 0.014	Threshold Mass data Review	Sher et al. (1951) Wapstra (1955) Mattauch et al. (1956)

See 58 Ka 1 for Cross sections

TABLE II  
 COMPARISON OF THRESHOLDS FROM MASS DATA AND FROM PHOTONEUTRON REACTIONS

Reaction	Photoneutron threshold, Mev.	Mass data threshold, Mev.	Difference, Mev.
Na <sup>22</sup> (γ, n)Na <sup>21</sup>	12.47 ± 0.05	12.47 ± 0.04	-0.05 ± 0.05
Al <sup>27</sup> (γ, n)Al <sup>26</sup>	12.96 ± 0.06	13.03 ± 0.06	-0.07 ± 0.03
Pt <sup>191</sup> (γ, n)Pt <sup>190</sup>	12.48 ± 0.05	12.39 ± 0.03	-0.09 ± 0.06
Co <sup>60</sup> (γ, n)Co <sup>59</sup>	10.44 ± 0.05	10.49 ± 0.01	-0.05 ± 0.05
Pt <sup>191</sup> (γ, n)Pt <sup>190</sup>	9.40 ± 0.05	9.30 ± 0.06	-0.10 ± 0.08

Elem. Sym.	A	Z
Na	23	11

Method  
NaI(Tl) detector; Li(p, $\gamma$ ) source

Ref. No.  
58 Ke 1 EH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
( $\gamma$ , p)	17.6					

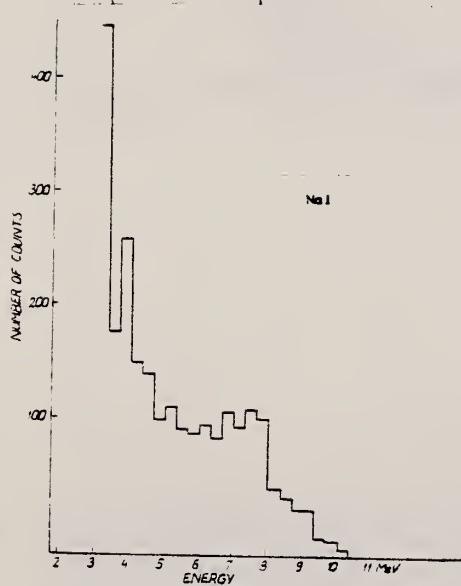


Fig. 6. Pulse spectrum of NaI crystal.

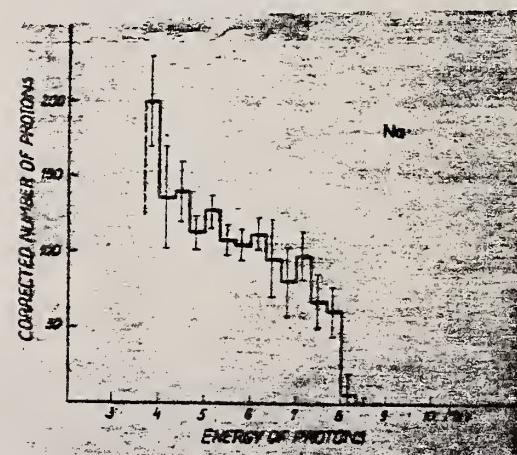


Fig. 8. Energy spectrum of protons from Na.

Elem. Sym.	A	Z
Na	23	11

Method  $\gamma$ -rays from  $\text{Li}^7(\text{p},\gamma)$  radiation; NaI(Tl) scintillator; proton spectra

Ref. No.  
 58 Op 1 EH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes																				
$\text{Na}^{23}(\gamma, p)$		17.6				<p>Energies of protons incident in Li were varied to permit identification of protons produced by 17.6 MeV component.</p> <table> <thead> <tr> <th>Outgoing Proton E</th> <th>Excitation of <math>\text{Ne}^{22}</math></th> <th><math>\sigma(\text{mb})</math></th> </tr> </thead> <tbody> <tr> <td>8.4</td> <td>0</td> <td>0.31</td> </tr> <tr> <td>7.2</td> <td>1.3</td> <td>2.5</td> </tr> <tr> <td>5.2</td> <td>3.5</td> <td>0.6</td> </tr> <tr> <td>4.1</td> <td>4.4</td> <td>0.9</td> </tr> <tr> <td>3.2</td> <td>5.4</td> <td rowspan="2">~ 2.0</td> </tr> <tr> <td>2.9</td> <td>5.7</td> </tr> </tbody> </table>	Outgoing Proton E	Excitation of $\text{Ne}^{22}$	$\sigma(\text{mb})$	8.4	0	0.31	7.2	1.3	2.5	5.2	3.5	0.6	4.1	4.4	0.9	3.2	5.4	~ 2.0	2.9	5.7
Outgoing Proton E	Excitation of $\text{Ne}^{22}$	$\sigma(\text{mb})$																								
8.4	0	0.31																								
7.2	1.3	2.5																								
5.2	3.5	0.6																								
4.1	4.4	0.9																								
3.2	5.4	~ 2.0																								
2.9	5.7																									

METHOD

Betatron

REF. NO.

59 Oc 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, 2N	RLI	THR-100	C	THR-100	ACT-I		4PI

REL TO G, N

TABLE II. Relative integrated cross sections.

Element	$(\gamma, n)$	Position of the peak for $(\gamma, n)$		Position of the peak for $(\gamma, 2n)$	
		( $\gamma, n$ )	( $\gamma, 2n$ )	( $\gamma, n$ )	( $\gamma, 2n$ )
C <sup>12</sup>	1	23 Mev	0.003	42 Mev	
N <sup>14</sup>	1	24 Mev	0.007*		
O <sup>16</sup>	1	22 Mev	0.002	40 Mev	
F <sup>19</sup>	1	20 Mev	0.14	32 Mev	
Na <sup>23</sup>	1	20 Mev	0.05	32 Mev	
Pu	1	20 Mev	0.06 ( $\gamma, 2p$ ) 0.08 ( $\gamma, 2pn$ )	45 Mev ( $\gamma, 2p$ ) 50 Mev ( $\gamma, 2pn$ )	

\* The ( $\gamma, n$ ) integrated cross section was taken from reference 4.

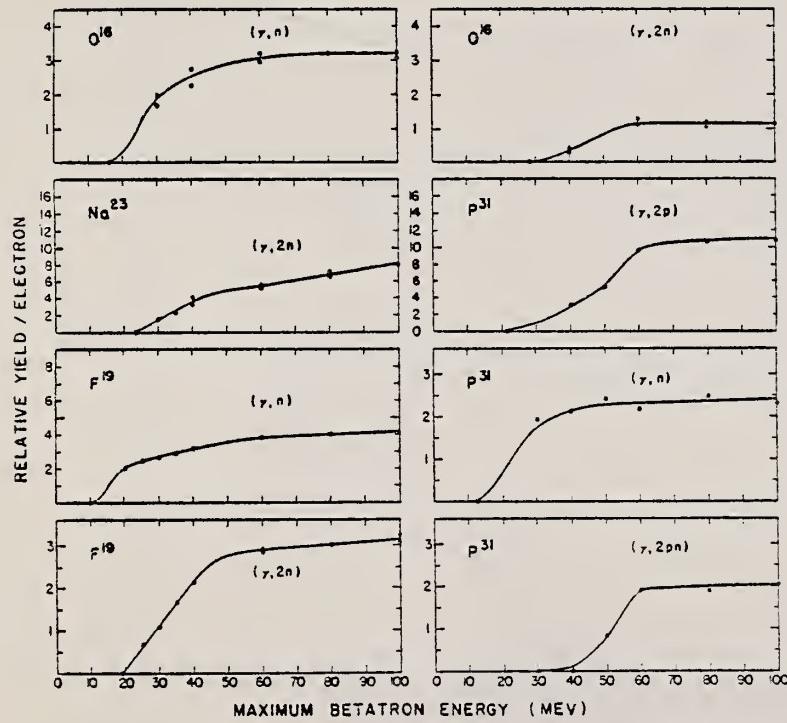


FIG. 1. The energy dependence of several photonuclear reactions. The relative yield scales of different graphs are independent.

Elem. Sym.	A	Z
Na	23	11

Method  $\text{Na}^{23}(\text{p},\text{p}')$  photon scattering; NaI spectrometer

Ref. No.  
 59 Ra 1 NVB

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$\text{Na}^{23}(\gamma,\gamma)$	2.78	440 keV				<p>Detectors at <math>115^\circ</math>, <math>151^\circ</math>.</p> <p>Intensity ratio:</p> $\frac{I(151^\circ)}{I(115^\circ)} = 1.10 \pm 0.04$ <p>Lifetime of first excited state:</p> $\tau = (1.8^{+0.4}_{-0.3}) \times 10^{-12} \text{ sec.}$

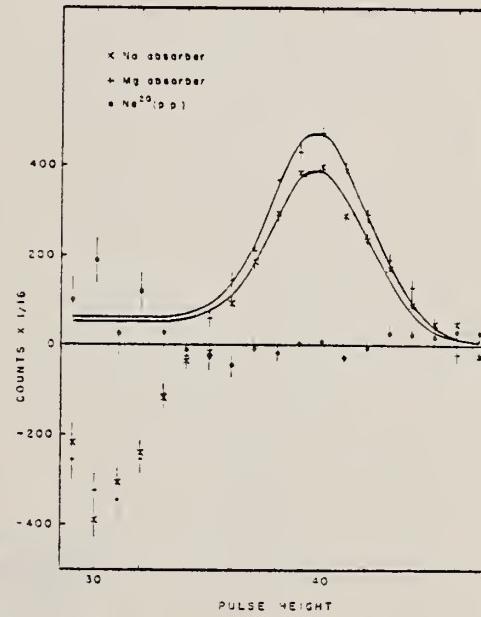


Fig. 4. Sodium scatterer-magnesium scatterer differences from the data shown in fig. 3. The shape of the solid curves is that observed with the 440-keV  $\gamma$ -ray from  $\text{Tl}^{202}$  adjusted slightly in pulse height to match the experimental points (it is *not* to be inferred that a precise comparison of the energies of these two  $\gamma$ -rays has been obtained). The negative differences at lower pulse heights result from small errors in the placement of the scatterers, as explained in the text. The sum of counts from pulse height 38 to 42 is taken to be proportional to the resonance effect.

Elem. Sym.	A	Z
Na	23	11

Method 800 kev cascade generator;  $\gamma$ 's from  $\text{Ne}^{22}(\text{p},\gamma)$ ; NaI

Ref. No.	
60 Mo 1	JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
( $\gamma,\gamma$ )	9.40		$2.7 \pm 1.1$ ev  $2.0 \pm 0.5$ ev			$\Gamma_{\gamma_0}$ by absorption integral.  $\Gamma_{\gamma_0}$ by yield measurement from $\text{Ne}^{22}(\text{p},\gamma)$  $E_p = 637$ kev; $\gamma$ energy varied to Doppler - compensate by changing angle with respect to proton beam.

METHOD

Synchrotron; proton-neutron cross section; radioactivity

REF. NO.

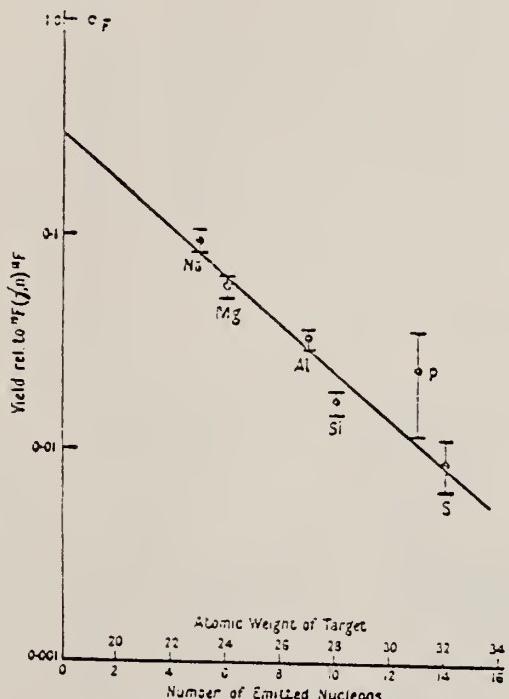
60 Wa 2

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, 3N2P	ABX	THR-240	C	120-240 (120, 180, 240)	ACT-I		4PI

$$\sigma = (0.33 \pm 0.03) 10^{-27} \text{ cm}^2 / \text{equivalent quantum}$$

Data (in Table) below 120 MeV from other workers;  
50 MeV data is that of Barber *et al.*, Phys. Rev.  
98, 73 (1955).



Yields relative to  $^{18}\text{F}(\gamma, n)^{18}\text{F}$  at 240 Mev.

Maximum bremsstrahlung energy (MeV)	Yield of $^{18}\text{F}$ from			$^{12}\text{C}(\gamma, n)^{11}\text{C}$ yield
	$^{18}\text{F}$	$^{23}\text{Na}$	$^{27}\text{Al}$	
240	1.83(17)	0.18(9)	0.062(13)	1.62
180	1.78(16)	0.18(16)	0.058(16)	1.50
120	1.6(14)	0.15(14)	0.045(14)	1.34
100	1.5	—	—	1.27
70	1.4	0.11	—	1.15
50	1.22	0.07	—	1.0

REF. B. Ambrozy, A. Faudrowicz, A. Jasinski, J. Kownacki, H. Lancman  
and J. Ludziejewski  
Proc. Int. Conf. Manchester 281 (1961)

ELEM. SYM.	A	Z
Na	23	11

METHOD

REF. NO.

Resonance Fluorescence

61 Am 1

JDM

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	1	D		NAI-D		120

Mean life of first excited state is  $\tau = 1.5^{(+0.3)}_{(-0.2)} 10^{-12}$  sec.

Elem. Sym.	A	Z
Na	23	11

Method 4 MeV electron Van de Graaff; brems.; nuclear resonance scattering, ring scatterer; NaI

Ref. No.  
62 Bo 6

JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$Na^{23}(\gamma, \gamma)$	Bremss. 0 - 4					$\theta = 110^\circ$

TABLE 3  
Mean lifetimes of excited states deduced from the resonance scattering of bremsstrahlung

Nucleus	$\tau_0$	Energy (MeV)	Spins	$g$	$\Gamma_0/\Gamma$	$\Omega''(g)$	$\tau < 10^4 \pm 35\%$ (sec)
$F^{19}$	100	1.46	$\frac{1}{2}^+$ - $\frac{3}{2}^+$	?	0.13	(1)	0.25 $\mu$
$Na^{23}$	100	2.08	$\frac{1}{2}^+$ - $\frac{3}{2}^+$	2	0.1	0.79	> 0.04
		2.39	-	?	0.33	(1)	> 1.6 $\mu$
		2.64	-	?	0.6	(1)	> 0.3 $\mu$
		2.70	-	?	(0.1)	(1)	> 0.008 $\mu$
		2.98	-	?	0.46	(1)	0.03 $\mu$
$Al^{27}$	100	2.73	$\frac{1}{2}^+$ - $\frac{3}{2}^+$	1	$\leq 0.3$	0.91	> 0.22
		2.98	-	?	0.216	1	$2.2 \times 10^{-4}$
$S^{31}$	4.71	1.28	$\frac{1}{2}^+$ - $\frac{3}{2}^+$	2	1	0.88	1.5
		2.43	-	?	(1)	0.88	0.2
$P^{31}$	100	1.26	$\frac{1}{2}^+$ - $\frac{3}{2}^+$	2	1	0.88	2.2
		2.23	-	?	0.79	4.3	
		3.13	-	2	(1)	0.88	0.2
		3.29	-	3	?	0.79	$> 1.8(\Gamma_0, \Gamma)^2$
		3.41	-	?	?	(1)	$> 1.3(\Gamma_0, \Gamma)^2$
		3.51	-	2	?	0.88	$> 0.02(\Gamma_0, \Gamma)^2$
$S^{33}$	95	3.73	$0^+$ - $\frac{3}{2}^+$	?	?	(1)	$> 0.62(\Gamma_0, \Gamma)^2$
$S^{33}$	4.2	2.127	$0^+$ - $\frac{3}{2}^+$	5	1	0.63	> 1.0
$Cl^{35}$	73.3	1.22	$\frac{1}{2}^+$ - $\frac{3}{2}^+$	?	1	(1)	0.9 $\mu$
		1.76	-	?	(1)	+	
		2.7(2.65)	-	?	?	(1)	$0.312(\Gamma_0, \Gamma)^2$
		3.01	-	?	?	(1)	$0.37g(\Gamma_0, \Gamma)^2$
$Cl^{37}$	73.3	3.1	-	?	?	(1)	$> 0.74(\Gamma_0, \Gamma)^2$
		3.17	-	?	?	(1)	$> 1.5(\Gamma_0, \Gamma)^2$
$Cl^{37}$	24.5	0.838	$\frac{1}{2}^+$ - $\frac{3}{2}^+$	?	1	(1)	> 1.3 $\mu$
		1.72	-	?	?	(1)	$> 0.82(\Gamma_0, \Gamma)^2$
$K^{39}$	93	2.53	$\frac{1}{2}^+$ - $\frac{3}{2}^+$	?	1	(1)	$> 1.6\mu$
		2.82	-	?	1	(1)	> 1.3 $\mu$
		3.02	-	?	1	(1)	0.35 $\mu$
		3.60	-	?	1	(1)	> 0.7 $\mu$
		3.88(3.94)	-	?	?	(1)	$0.14(\Gamma_0, \Gamma)^2$
		4.06(4.12)	-	?	?	(1)	$> 0.22(\Gamma_0, \Gamma)^2$
$Cu^{49}$	96	3.90	$0^+$ - $\frac{3}{2}^+$	3	1	0.63	> 0.46
$Cu^{49}$	69	1.33	$\frac{1}{2}^+$ - $\frac{3}{2}^+$	2	(1)	0.8	$4.4 > \tau > 11$

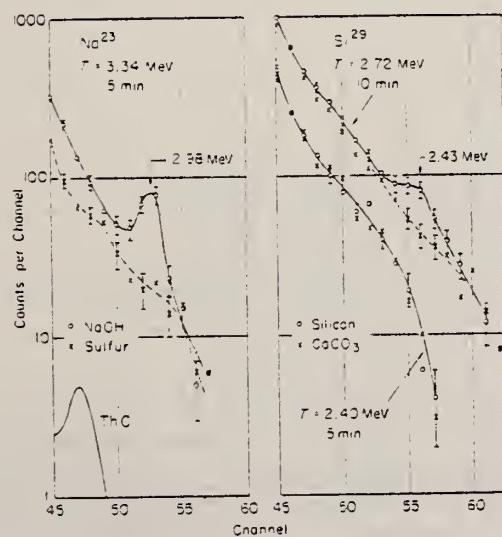


Fig. 3. Resonance fluorescence from the 2.94 MeV state of  $Na^{23}$  and the 2.43 MeV state of  $Si^{29}$ .  
The ThC peak is at 2.615 MeV.  $T$  is the maximum bremsstrahlung energy.

The factor  $g$  equals  $(M-1)/(M_0-1)^{-1}$ .

Elem. Sym.	A	Z
Na	23	11

Method  
 "Liverpool University H.T. set"; NaI

Ref. No.
62 Br 2

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
Ne <sup>22</sup> (p, $\gamma$ )	440-1030 keV	9.43±0.05			$\frac{1}{2}^+ (\frac{1}{2})^-$	$E_p = 636$ keV; 82% to ground state.
		9.59±0.05			$3/2^+$	$p_o = 854$ keV; 28% to ground state.
		9.67±0.03			$5/2^+$	= 902 keV; 37% to ground state.
		9.70±0.04			$3/2^+$	= 952 keV; 50% to ground state.
		9.78±0.04			$3/2^+$	= 1014 keV; 10% to ground state.

$$\omega(\theta) = a_0 P_0(\cos\theta) + a_2 P_2(\cos\theta) \\ + a_4 P_4(\cos\theta);$$

parameters in Table 6.

TABLE 6  
 Angular distributions

Resonance	Transition	$a_2$	$a_4$
all isotropic			
836 keV	$\pi \rightarrow 0$	0.70±0.03	0.01±0.02
	$\pi \rightarrow 1$	-0.14±0.03	-0.03±0.03
902 keV	$\pi \rightarrow 0$	0.47±0.06	0.17±0.06
	$\pi \rightarrow 1$	0.53±0.11	0.0±0.04
	$\pi \rightarrow 7$	-0.04±0.07	0.07±0.04
	$\pi \rightarrow 11$	-0.18±0.03	-0.03±0.03
11±1	$\pi \rightarrow 1$	-0.02±0.02	-0.08±0.03
7±1	$\pi \rightarrow 1$	-0.05±0.06	0.06±0.07
4±0	$\pi \rightarrow 0$	0.17±0.06	0.05±0.07
952 keV	$\pi \rightarrow 0$	0.28±0.05	0.02±0.04
	$\pi \rightarrow 1$	-0.04±0.03	-0.03±0.04
	$\pi \rightarrow 4$	-0.48±0.03	-0.03±0.1
	$\pi \rightarrow 6$	0.30±0.09	0.07±0.2
	$\pi \rightarrow 0$	0.13±0.08	-0.02±0.09
	$\pi \rightarrow 1$	0.06±0.03	0.09±0.06
	$\pi \rightarrow 4$	-0.02±0.03	0.08±0.06
1014 keV	$\pi \rightarrow 0$	-0.23±0.01	0.04±0.01
	$\pi \rightarrow 1$	-0.00±0.04	-0.07±0.04
	$\pi \rightarrow 4$	-0.24±0.03	0.04±0.03
	$\pi \rightarrow 7$	0.36±0.05	0.12±0.05
	$\pi \rightarrow 1$	-0.03±0.02	0.0±0.03
	$\pi \rightarrow 4$	-0.02±0.02	0.04±0.02
Triple correlations			
636 keV	$\pi \rightarrow 0 \rightarrow 0$ , types I and II	0.28±0.06	-0.05±0.2
	$\pi \rightarrow 7 \rightarrow 1$ , types I and II	0.04±0.1	0.01±0.2
	$\pi \rightarrow 10 \rightarrow 0$ , types I and II	0.06±0.1	0±0.1
854 keV	$\pi \rightarrow 1 \rightarrow 0$ , type I	-0.19±0.01	-0.01±0.01
	$\pi \rightarrow 1 \rightarrow 0$ , type II	-0.21±0.01	-0.01±0.01
902 keV	$\pi \rightarrow 1 \rightarrow 0$ , type I	0.75±0.05	-0.04±0.03
	$\pi \rightarrow 1 \rightarrow 0$ , type II	0.02±0.03	-0.02±0.04
	$\pi \rightarrow 7 \rightarrow 1$ , type II	-0.04±0.07	-0.06±0.09
952 keV	$\pi \rightarrow 11 \rightarrow 1$ , type I	-0.04±0.06	0.09±0.08
	$\pi \rightarrow 11 \rightarrow 1$ , type II	0.01±0.05	-0.09±0.07
	$\pi \rightarrow 11 \rightarrow 2$ , type II	0.34±0.15	-0.17±0.29
1014 keV	$\pi \rightarrow 1 \rightarrow 0$ , type I	-0.02±0.04	0±0.04
	$\pi \rightarrow 1 \rightarrow 0$ , type II	-0.21±0.02	-0.03±0.02
	$\pi \rightarrow 4 \rightarrow 0$ , type I	0.50±0.32	-0.02±0.20
	$\pi \rightarrow 4 \rightarrow 0$ , type II	0.06±0.16	0.06±0.18

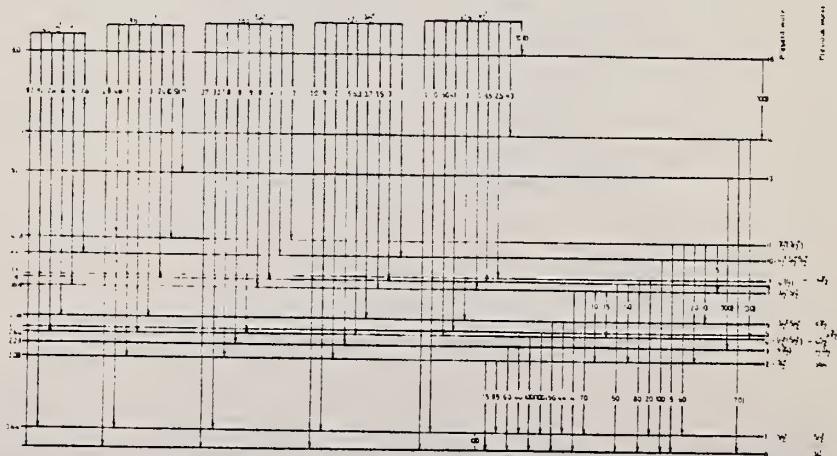


Fig. 9. Decay schemes, spins and parities

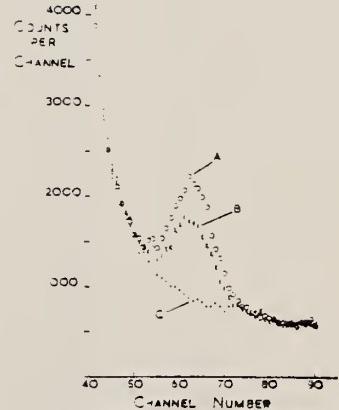
Elem. Sym.	A	Z
Na	23	11

Method 1.4 MeV electron accelerator; NaI

Ref. No.  
 62 Mo 1 JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$^{23}\text{Na}(\gamma, \gamma)$	Bremss; 600 kev	440 kev	$(3.66 \pm 0.50) \times 10^{-4}$ ev			This $\Gamma$ gives a mean lifetime of $t = (1.80 \pm 0.28) \times 10^{-12}$ sec. Scattering angle $150^\circ$

FIG. 3. Results for scattering from sodium. Curve A: sodium scatterer with aluminum absorber. Curve B: sodium scatterer with sodium absorber. Curve C: aluminum scatterer with sodium absorber.



Elem. Sym.	A	Z
Na	23	11

Method

Synchrotron; foils; emulsions

Ref. No.

620dl

BG

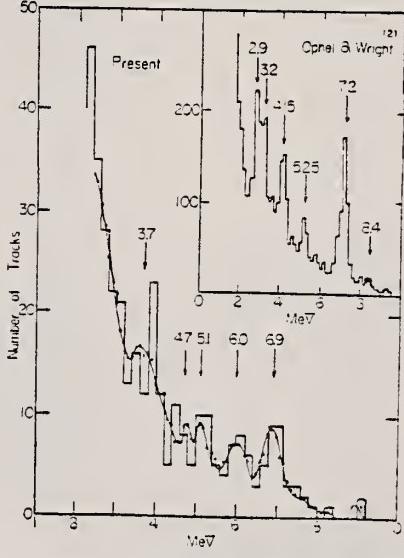
Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$(\gamma, p)$	bremss.; $E_{\gamma\max} = 18\text{ MeV}$			$1.1 \times 10^5 \text{ protons/mol/roentgen}$		<p>Energy (Fig.1) and angular distribution (Fig.2)  Angular distributions fit <math>A(1 + \cos^2\theta)</math></p> 

Fig. 1. Energy spectrum of photoprotons from Na. Irradiation by 18 MeV bremsstrahlung. The inset shows the result of Ophel and Wright.<sup>21</sup>

\* Present address: Institute of Physical and Chemical Research, Bunkyo-ku, Tokyo.

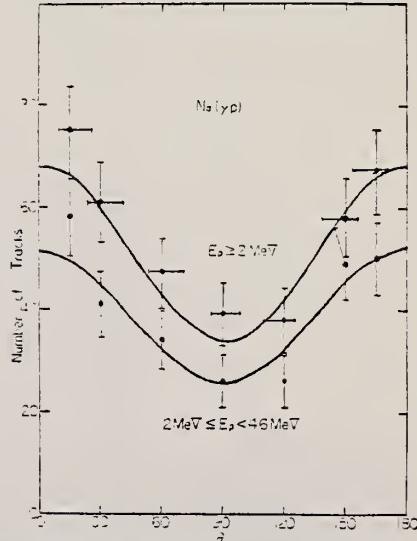


Fig. 2. Angular distributions of photoprotons from Na. Upper one is for all protons measured and lower one is for those below 4.6 MeV. Solid curves are  $A(1 + \cos^2\theta)$ .

Elem. Sym.	A	Z
Na	23	11

Method

Lines (Stanford Mark II) - counter telescope

Ref. No.

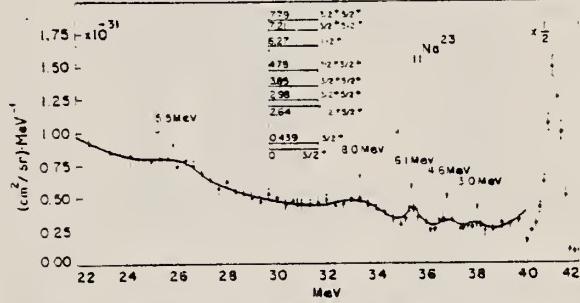
65Bal

BG

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
(e,e')	41.5		determined see Table II		see Table II	inelastic scattering cross section ( $\text{cm}^2/\text{sr}$ ) $\times 10^{-32}$ at $180^\circ$
		3.0		0.02 MeV- $\mu$ b		$0.2 \pm 50\%$
		4.6		0.07		$0.5 \pm 40\%$
		6.1		0.20		$1.0 \pm 40\%$
		8.0		0.68		$2.5 \pm 30\%$

TABLE 2

Isotope	Energy of level (MeV)	Spin and parity		Inelastic electron scattering cross section ( $\text{cm}^2/\text{sr}$ ) $\times 10^{-38}$			Radiation width to ground state (eV)	Weiss- kopf
		Ground state	Excited state	Estimated error (%)	MeV- $\mu$ b	This experi- ment (*)		
$_{11}\text{Li}^+$	3.56	$1^+$	$0^+$	4.0	20	0.42	4.7	0.82
	5.7	$1^+$	$1^+$	0.15	50	0.03	0.9	3.6
		$1^+$	$2^+$				0.3	
		$0^+$	$1^+$				0.16	
	9.3	$1^+$	$1^+$	0.6	30	0.20	1.5	15
		$1^+$	$2^+$				1.3	
		$0^+$	$1^+$				2.4	
	14.0	$1^+$	$1^+$	0.25	50	0.14	3.3	58
		$1^+$	$2^+$				5.5	
		$0^+$	$1^+$				37.5	
	15.8	$1^+$	$1^+$	0.25	50	0.17	12.5	80
		$1^+$	$2^+$				7.5	
$_{11}\text{Li}^+$	9.6	$1^+$	$1^+$	0.18	50	0.06	3.4	18
		$1^+$	$2^+$				1.1	
	10.5	$1^+$	$1^+$	0.78	30	0.30	19.2	23
		$1^+$	$2^+$				9.6	
	14.0	$1^+$	$1^+$	0.48	40	0.27	6.4	53
		$1^+$	$2^+$				31.2	
		$0^+$	$1^+$				15.6	
		$1^+$	$2^+$				10.4	
		$0^+$	$1^+$				23.4	
$_{14}\text{N}^{14}$	9.3	$1^+$	$1^+$	0.92	30	0.30	7.8	17
		$1^+$	$2^+$				4.6	
		$0^+$	$1^+$				24.6	
	10.6	$1^+$	$1^+$	0.65	30	0.25	5.2	25
		$1^+$	$2^+$				4.9	
$_{16}\text{O}^{16}$	19.0	$0^+$	$1^+$	0.45	40	0.41	14.1	145
$_{19}\text{F}^{19}$	7.7	$1^+$	$1^+$	2.0	25	0.54	4.7	9.0
$^{10}\text{Ne}^{10}$	$\approx 9$	$0^+$	$1^+$	3.0	20	0.9	7.1	14.5
	$\approx 13$	$1^+$	$1^+$	2.0	20	1.0	16.6	43
$_{23}\text{Na}^{23}$	3.0	$1^+$	$1^+$	0.2	50	0.02	0.05	0.45
		$1^+$	$2^+$				0.035	
	4.6	$1^+$	$1^+$	0.5	40	0.07	0.43	1.3
	5.1	$1^+$	$1^+$	1.0	40	0.20	4.4	4.6
	3.0	$1^+$	$2^+$	2.5	30	0.68	12.3	10.8
		$1^+$	$2^+$				1.46	
$_{24}\text{Mg}^{24}$	11.0	$0^+$	$1^+$	4.4	20	1.76	21.0	29
	$\approx 14$	$1^+$	$1^+$	1.5	30	0.83	15.3	53
$_{13}\text{Al}^{13}$	4.3	$1^+$	$1^+$	0.7	30	0.10	0.67	2.1
		$1^+$	$2^+$				0.50	
	8.0	$1^+$	$1^+$	1.9	30	0.50	14.0	10.8
		$1^+$	$2^+$				9.3	
		$0^+$	$1^+$				7.0	

Fig. 11. Spectrum of 41.5 MeV electrons scattered from  $\text{Na}^{23}$  at  $180^\circ$ .

Method	100 MeV Synchrotron; 4 $\pi$ neutron detector; calculated integrated cross sections - fitted with polynomial of degree $\eta$	Ref. No.
		63 Co 3

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$Na^{23}(\gamma, xn)$						$\sigma_b = \int \frac{\sigma(E)}{E} dE$ <p>gets <math>\langle \bar{v}_p \cdot \bar{v}_n - \bar{v}_n \cdot \bar{v}_n \rangle</math></p> $= (R_c^2 - R_p^2 - \frac{3}{\pi^2} \frac{\text{tr } c}{e^2} \sigma_b \frac{A-1}{A^2}) \times \frac{2}{A-2}$ <p>See "Boron" for plots of this and <math>\int \sigma dE / 60 NZ/A</math>.</p>

Fig. 1. Photoneutron cross sections for several light elements versus  $\gamma$ -ray energy.

METHOD

Betatron; neutron cross sections;  $\text{BF}_3$  counters; ion chamber

REF. NO.

63 Sa 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XN	ABX	12 - 24	C	12 - 24	$\text{BF}_3$ - I		4 PI

781

a, b in Table I refer to two Lorentz shaped peaks in the split giant resonance.

-24 2

Quadrupole moment  $Q_0 = 0.3 \times 10^{-24} \text{ cm}^5$ , based on Danos' theory.

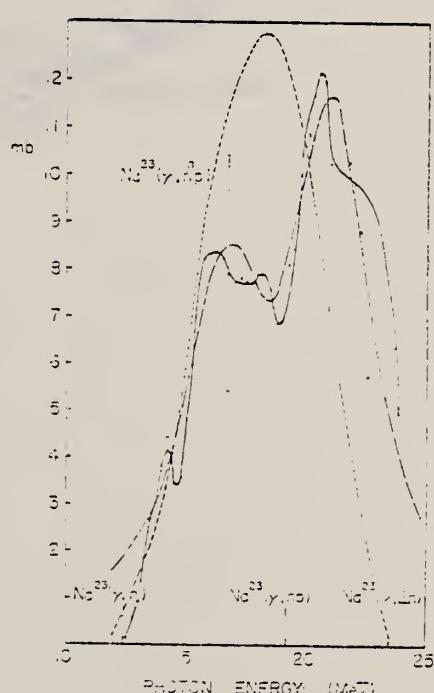


Fig. 2. The  $(\gamma, n) + (7, np)$  cross sections for  $\text{Na}^{23}$  and fitting the cross section to the superposition of two Lorentz lines.

Solid line: present data obtained from the yield curve for the summation of the 7 runs.

Dotted line: data of Montalbetti et al.<sup>8)</sup>.

Broken line: the superposition of two Lorentz lines which is calculated from the parameters given in Table I.

The arrows in the figure show the threshold energies.

- 8) R. Montalbetti, L. Katz and J. Goldemberg:  
Phys. Rev. 91 (1953) 659.

Table I. Resonance Parameters

	$\text{Na}^{23}$	$\text{Si}^{28}$
$E_a$	16.5 Mev	18.75 Mev
$\sigma_a$	6.8 mb	11.0 mb
$\Gamma_a$	4.0 Mev	2.0 Mev
$E_b$	21.0 Mev	20.75 Mev
$\sigma_b$	10.5 mb	13.0 mb
$\Gamma_b$	4.0 Mev	2.6 Mev

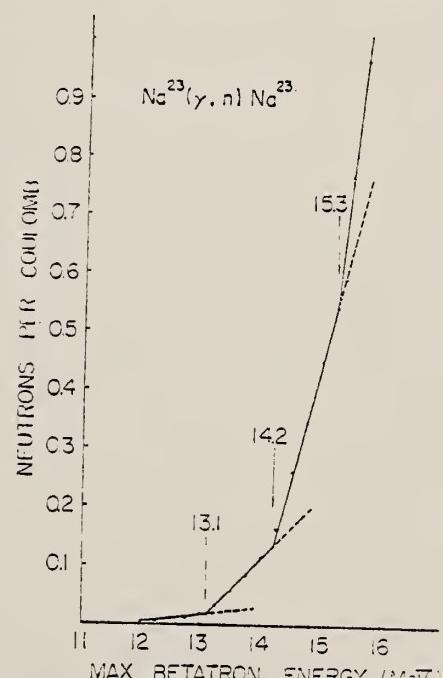


Fig. 4. The breaks in the  $\text{Na}^{23} (\gamma, n) \text{Na}^{23}$  yield curve.

## METHOD

Betatron

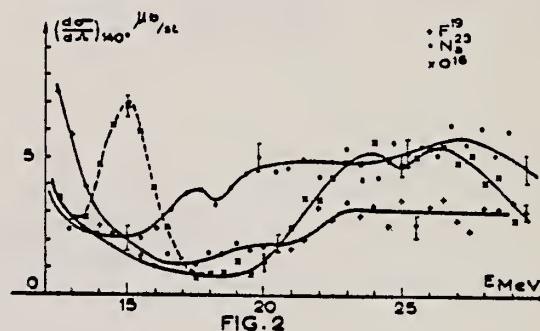
REF. NO.

64 Lo 3

JDM

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	ABX	10-30	C	10-30	NAI-D		140

The effective differential scattering cross section remains quite constant from 20-30 MeV.



METHOD Van de Graaff; N <sup>15</sup> (p,γ)C <sup>12*</sup> source.					REF. NO. 64 Me 1	NVB	
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	4 (4.431)	D	4 (4.431)	NAI-D		DST

J<sup>π</sup> =  $\frac{1}{2}^-$  for 4.431 MeV level.

J-PI, WIDTH

$\Gamma^0 = (2.14 \pm 0.10)\text{eV}$  (partial width for ground state transitions)

$\Gamma = (2.25 \pm 0.20)\text{eV}$ , or  $\tau = (2.9 \pm 0.3) \times 10^{-16}$  sec.

REF.

F. R. Metzger  
Proc. Paris Conference 392 (1964)

ELEM. SYM.	A	Z
Na	23	11

## METHOD

REF. NO.

Resonance Scattering  $^{15}\text{N}(\text{p},\alpha\gamma)^{12}\text{C}$ 

64 Me 2

JDM

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	4	D	4	NAI-D	4	DST

The 4.431 MeV state in  $^{23}\text{Na}$  has spin  $\frac{1}{2}$  and  $\Gamma_0 = (2.1 \pm 0.1)\text{eV}$ .

METHOD

Van de Graaff;  $F^{19}(p, \nu)O^{16}$ \* source

REF. NO.  
64 Sw 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G.G	NOX	7 ( $7.10 \pm 0.02$ )	D	7, 7 ( $6.91, 7.12$ )	NAI-D		DST

J-PI, WIDTH

Found level energy to be  $7.10 \pm 0.02$  MeV.

Angular distribution

$$W(\theta) = 1 + (0.47 \pm 0.09)P_2 + (0.32 \pm 0.03)P_4.$$

$$J^{\pi} = \frac{5}{2}^{+}$$

$\Gamma_0 = (0.62 \pm 0.07)$  eV (partial width for ground state transition)

$\Gamma = (0.98 \pm 0.12)$  eV (total width)

Quadrupole-dipole amplitude ratio ( $E2-M1$ )  $\delta$ :

$$-1.3 < \delta < -2.2$$

$$\text{or } 2.5 < \delta < 3.0$$

CHEM. SYM.	Na	23	11
------------	----	----	----

METHOD	REF. NO.				
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
E, E/	ABX	4	D 59	MAG-D 50-59	180

$$\int \sigma \gamma d\epsilon = 63.3 \text{ } \mu\text{b-MeV}$$

Level at 4.431 MeV.

$$g\Gamma_0 = .32 \pm .03 \text{ eV}$$

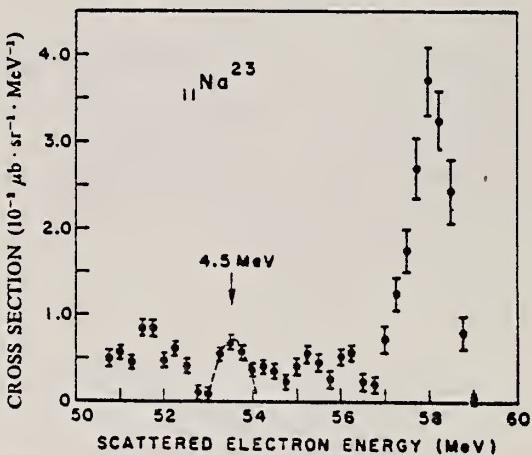


Fig. 1. Energy distribution of 58.5 MeV electrons, scattered elastically and inelastically at 180° from a <sup>23</sup>Na target, after correction for radiative effects. The dashed curve shows the area used in evaluating the cross section.

## METHOD

REF. NO.

Synchrotron; ion chamber monitor

65 Wy 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, MU-T	ABX	10 - 35	C	90	SCI-D		4PI

49

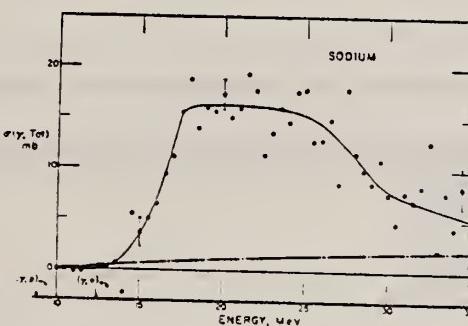


FIG. 11. Sodium total photonuclear cross section.

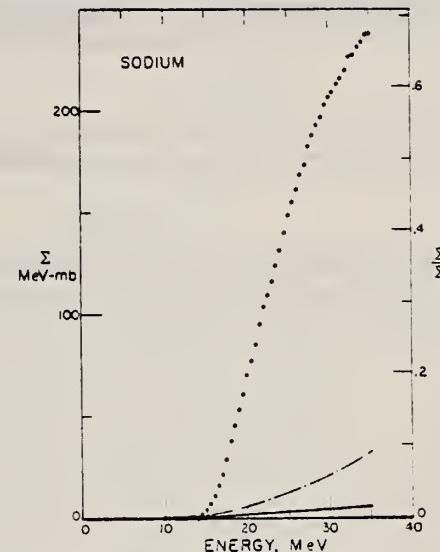


FIG. 12. Sodium total photonuclear cross section integrated over energy.

ELEM. SYM.	A	Z
Na	23	11

METHOD

REF. NO.

[Page 1 of 2]

66 We 1

JDM

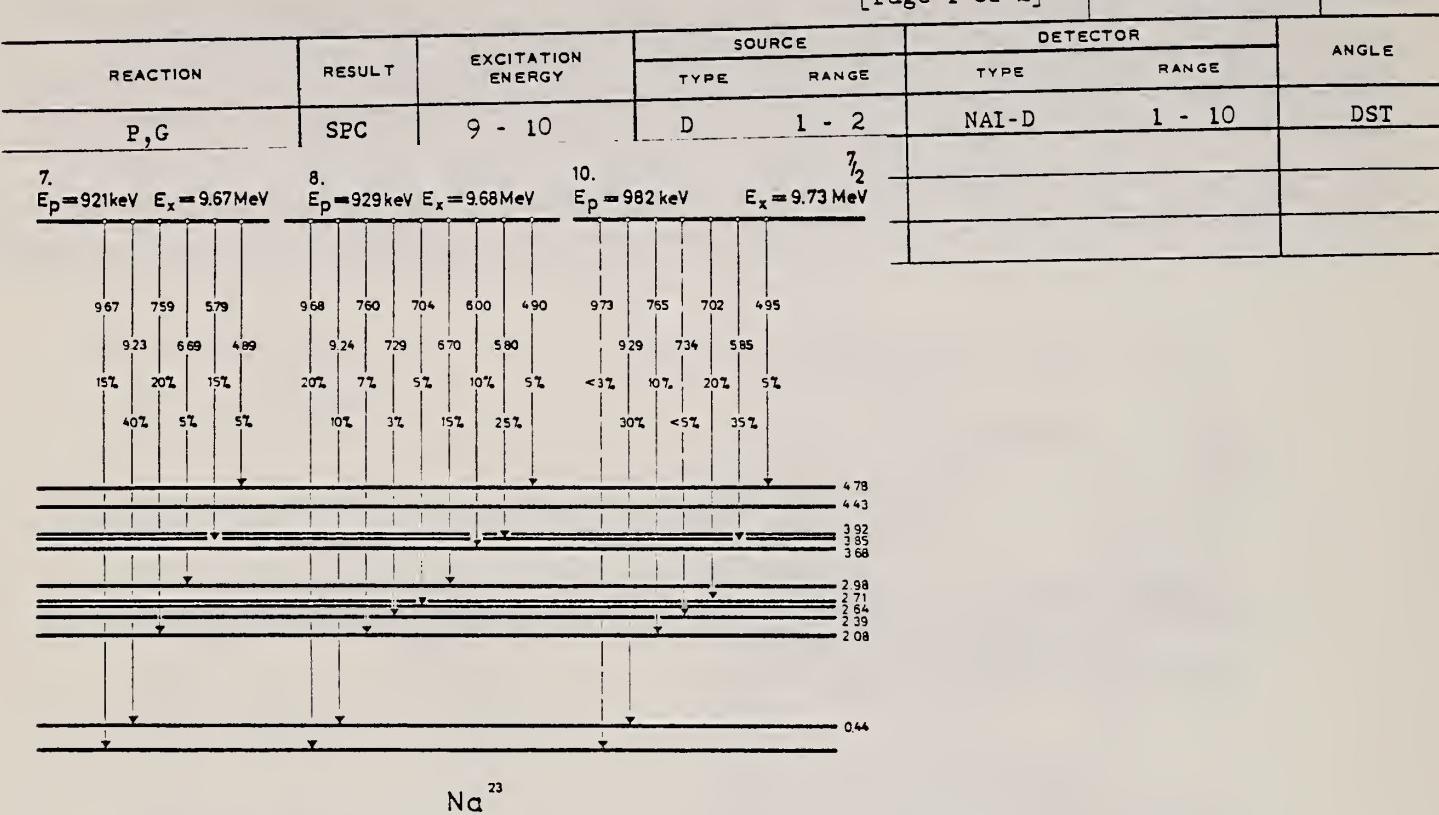


Fig. 22. Decay schemes of the 921 keV, 929 keV and 982 keV resonances.

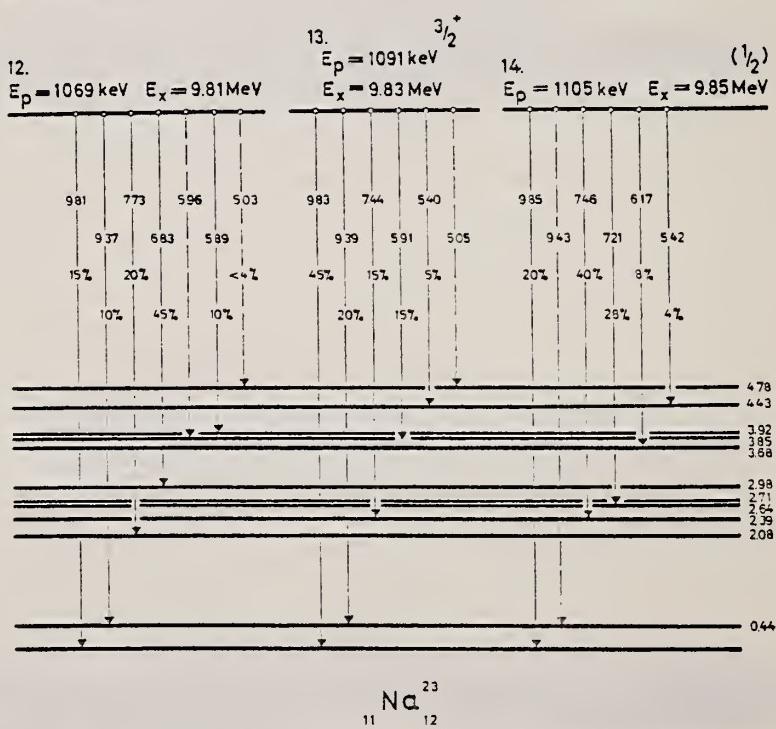


Fig. 23. Decay schemes of the 1069 keV, 1091 keV and 1105 keV resonances.

ELEM. SYM.	A	Z
Na	23	11

METHOD

REF. NO.

[Page 2 of 2]

66 We 1

JDM

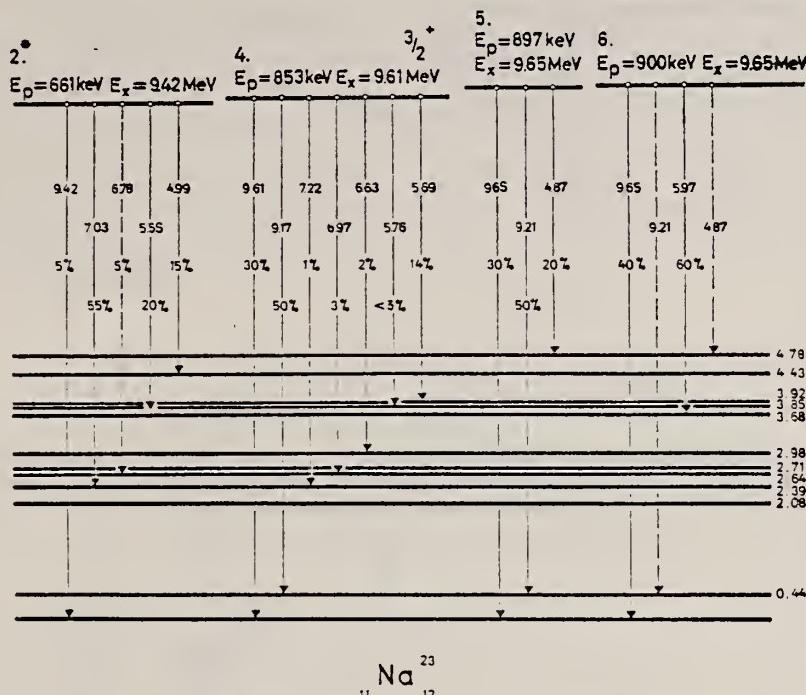


Fig. 21. Decay schemes of the 661 keV, 853 keV, 897 keV and 900 keV resonances. The spin value of the 853 keV capturing state from Braben *et al.* [3].

\*The figure refers to the resonance number given in ref. 1.

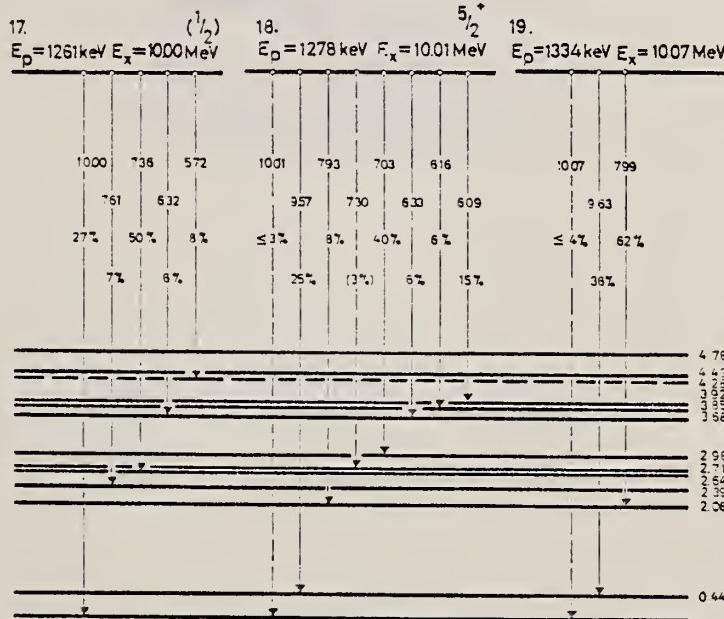


Fig. 24. Decay schemes of the 1261 keV, 1278 keV and 1334 keV resonances.

METHOD

REF. NO.

67 Fe 3

EGF

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
O, G	ABX	23-29	D	12-31	NAI-D	20-30	90

Li7 + O16

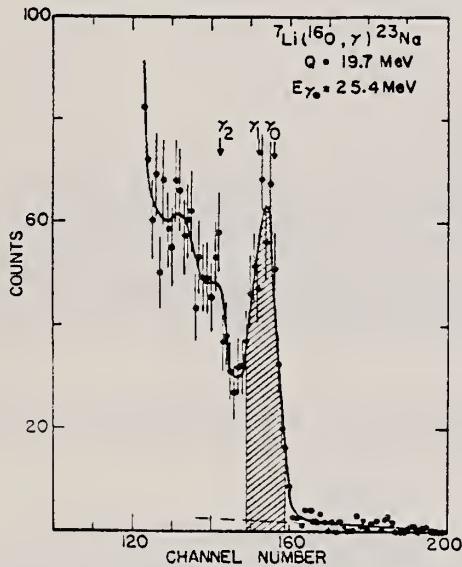


Fig. 1. The high-energy portion of a  $\gamma$  ray spectrum from  ${}^7\text{Li}({}^{16}\text{O}, \gamma){}^{23}\text{Na}$  for  $E({}^{16}\text{O}) = 19.4 \text{ MeV}$ . The shaded region was summed for the excitation function. The cosmic-ray background in the peak region is indicated by a dashed line.

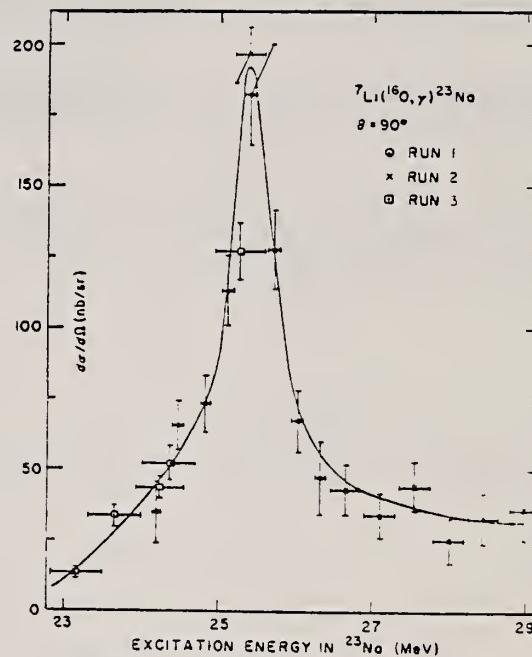


Fig. 2. The excitation function of the unresolved gamma transitions to the ground- and first-excited states of  ${}^{23}\text{Na}$  for the reaction  ${}^7\text{Li}({}^{16}\text{O}, \gamma){}^{23}\text{Na}$ .

REF.

J. M. Loiseaux, J. M. Maison, and M. Langevin  
 J. de Physique 28, 11 (1967)

ELEM. SYM.	A	Z
Na	23	11

METHOD

REF. NO.

67 Lo 1

JOC

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, G/	ABX	15-30	C	34	NAI-D		DST

TABLEAU I

COEFFICIENT  $\alpha$  DES DISTRIBUTIONS ANGULAIRES

$$W(\theta) = 1 + \alpha \cos^2 \theta$$

$^{16}\text{O}$ .....	$\alpha(19-25 \text{ MeV}) = 1 \pm 0.1$	$\alpha(18,5-23 \text{ MeV}) = 0,4 \pm 0,15$	$\alpha(25-30 \text{ MeV}) = 0,85 \pm 0,2$
$^{23}\text{Na}$ .....	$\alpha(15-18 \text{ MeV}) = 0,1 \pm 0,1$	$\alpha(18,5-23 \text{ MeV}) = 0,4 \pm 0,15$	$\alpha(25-30 \text{ MeV}) = 0,85 \pm 0,2$
$^{24}\text{Mg}$ .....	$\alpha(16,5-20 \text{ MeV}) = 0,3 \pm 0,1$	$\alpha(20-25 \text{ MeV}) = 0,5 \pm 0,1$	$\alpha(25,5-32 \text{ MeV}) = 0,5 \pm 0,1$
$^{28}\text{Si}$ .....	$\alpha(15-17,5 \text{ MeV}) = 0,87 \pm 0,1$	$\alpha(18-23 \text{ MeV}) = 0,7 \pm 0,1$	$\alpha(25,5-32 \text{ MeV}) = 0,5 \pm 0,1$
$^{39}\text{K}$ .....	$\alpha(14,5-18,5 \text{ MeV}) = 0,5 \pm 0,1$	$\alpha(19-24,5 \text{ MeV}) = 1 \pm 0,1$	$\alpha(25-32 \text{ MeV}) = 1 \pm 0,1$

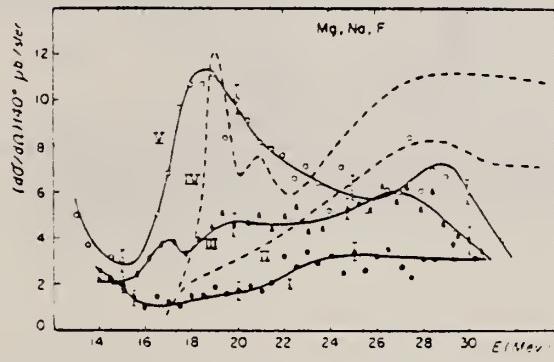


FIG. 6.

Sections efficaces différentielles de diffusion à 140° pour  $^{16}\text{O}$  (I),  $^{23}\text{Na}$  (III) et Mg (V).

Section efficace prévue par la relation de dispersion pour  $^{23}\text{Na}$  (courbe II) et Mg (courbe IV).

REF.

G. A. Savitskii, N. G. Afanas'ev, I. S. Gul'karov, V. D. Kovalev,  
 I. V. Andreeva, V. M. Khvastunov, N. G. Shevchenko  
 Ukr. Fiz. Zhur. 13, 1648 (1968)  
 Ukr. J. Phys. 13, 1174 (1969)

ELEM. SYM.

Z

Na 23

11

METHOD

REF. NO.

68 Sa 3

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	FMF	2,7	D	225	MAG-D		DST

TABLE 3. Squared Form Factor for Inelastic Scattering with Excitation of the 2.08 MeV Level in  $\text{Na}^{23}$

$$2=2.08, 7=6.27+7.10$$

$q'$ , fermi $^{-1}$	$F^2 \cdot 10^4$	$q'$ , fermi $^{-1}$	$F^2 \cdot 10^4$
0.41	13.9 ± 13.9	1.26	14.5 ± 1.2
0.51	20.1 ± 13.7	1.35	11.1 ± 0.9
0.61	24.2 ± 14.7	1.41	7.16 ± 0.67
0.71	32.1 ± 9.1	1.45	7.20 ± 0.50
0.71	22.0 ± 10.3	1.48	6.52 ± 0.51
0.80	15.8 ± 10.8	1.51	5.71 ± 0.43
0.90	70.3 ± 9.1	1.55	4.13 ± 0.35
0.90	31.0 ± 8.9	1.73	1.57 ± 0.15
0.90	46.3 ± 5.0	1.865	1.11 ± 0.11
1.08	31.2 ± 2.9	1.98	0.91 ± 0.12
1.17	29.8 ± 1.7	2.08	1.67 ± 0.20

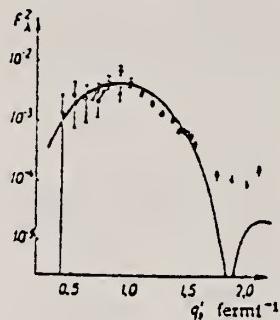


Fig. 3. Form factor for inelastic scattering of electrons with excitation of the 2.08 MeV level in  $\text{Na}^{23}$ .

TABLE 4. Differential Cross Sections for Inelastic Scattering of Electrons Having an Initial Energy of 225 MeV with Excitation of the 6.27 and 7.10 MeV Levels in  $\text{Na}^{23}$ , Which Were Not Resolved Experimentally

$\theta$	$\sigma_{\text{exp}} \cdot 10^{32}$ , cm $^2/\text{sr}$	$\theta$	$\sigma_{\text{exp}} \cdot 10^{32}$ , cm $^2/\text{sr}$
30	667 ± 251	74	47.7 ± 5.2
35	454 ± 125	76	46.2 ± 1.2
35	351 ± 131	78	40.6 ± 3.6
40	132 ± 54	78	36.8 ± 3.3
45	76.2 ± 17.0	80	30.5 ± 2.7
45	78.0 ± 16.9	82	27.1 ± 2.5
50	42.8 ± 9.9	85	12.1 ± 1.5
55	75.1 ± 4.4	95	8.20 ± 1.08
60	20.7 ± 2.4	105	5.30 ± 0.85
65	9.01 ± 1.10	115	2.70 ± 0.64
70	6.96 ± 0.98	125	1.35 ± 0.46

REF.

K. Shoda, K. Abe, T. Ishizuka, N. Kawamura, M. Oyamada,  
and Baik-Nung Sung  
J. Phys. Soc. Japan 25, 664 (1968)

ELEM. SYM.	A	Z
Na	23	11

METHOD

REF. NO.

68 Sh 3

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XP	SPC	20-24	D	20, 24	EMU-D	2-14	DST

Table III. Anisotropic factor  $B/A$  of angular distributions estimated for the groups of strong transitions.

	Assumed residual Energy (MeV)	$E_\gamma$ (MeV)	$B/A$	Used data <sup>a</sup>
<sup>23</sup> Na	1.27	18.8-20.5	0.5±0.4	20.5
	3.3	{ 20.8-22.1	∞ <sup>b</sup>	D
	7.0	{ 22.1-24	∞ <sup>b</sup>	24.0
<sup>23</sup> P	0	15.7-21	∞ <sup>b</sup>	24.0, 19.0
	7.0	{ 17.4-20.2	0.5±0.6	D
		{ 20.2-22.7	1.3±1.3	D
<sup>23</sup> S	0	{ 14-20	∞ <sup>b</sup>	(p, 7s)
		{ 14-14.8	2.4±0.7	17.0
		{ 14.8-16.2	∞ <sup>b</sup>	17.0
		{ 16.2-17.1	∞ <sup>b</sup>	17.0
	5.0	{ 19.2-20.1	0.5±0.2	D
<sup>40</sup> Ca	0	{ 20.1-21.3	0.4±0.2	D
	2.8	17.1-20.5	1.5±0.2	20.5
		17.4-19.9	2.6±0.3	20.5
	6.0	{ 17.2-18.7	0.05±0.09	20.5
		{ 18.7-20.5	0.6±0.1	20.5

a) The numerical number indicates the maximum energy of the bremsstrahlung irradiated for the data.  
D shows the difference between the two distributions. (p, 7s) shows the inverse reaction data.

b) The notation ∞ indicates that the distribution is almost  $\sin^2 \theta$ , i.e., the result has stronger maximum than  $1+10\sin^2 \theta$ .

Table II. Anisotropic factor  $B/A$  of angular distributions determined by least-squares fits with  $A+B\sin^2 \theta$ .

<sup>23</sup> Na					
(E <sub>y</sub> <sub>max</sub> =20.5 MeV)		(E <sub>y</sub> <sub>max</sub> =24.0 MeV)		(Curve D in Fig. 1)	
E <sub>p</sub> (MeV)	B/A	E <sub>p</sub> (MeV)	B/A	E <sub>p</sub> (MeV)	B/A
2.5-4.6	1.6±0.6	4.7-6.5	1.3±0.2	4.7-6.6	1.5±0.3
4.6-6.7	1.0±0.2	6.5-8.3	3.4±1.1	6.6-8.3	6.1±1.3
6.7-8.4	1.6±0.7	8.3-9.6	9.6±6.1	8.3-9.6	∞ <sup>b</sup>
8.4≤	0.5±0.4	9.6≤	∞ <sup>b</sup>	9.6≤	∞ <sup>b</sup>
2.5≤	1.4±0.4	3.5≤	1.9±0.3		

a) The notation ∞ indicates that the distribution is almost  $\sin^2 \theta$ . It is used when the result has stronger maximum than that of  $1+10\sin^2 \theta$ .

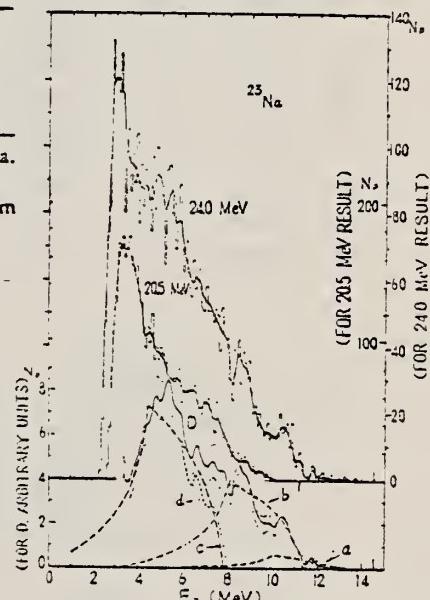


Fig. 1. Energy distributions of photoprottons from <sup>23</sup>Na irradiated with 20.5 MeV and 24.0 MeV bremsstrahlung. Curve D and its error brackets (dotted curves) show the spectrum made by difference of the two results. Curves a, b and c, respectively showing the transitions leaving the residual nucleus in 1.27, 3.3 and 7.0 MeV, are component spectra for curve D. Curve d is the difference spectrum between curve b and curve D.

METHOD					REF. NO.		
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XP	ABY	THR- 33	C	24-33	SCI-D	3-14	90

Tabelle 1. Daten zu den einzelnen Reaktionen. Die Werte für den integrierten Wirkungsquerschnitt wurden unter der Annahme ausschließlicher Grundzustandsübergänge berechnet. Für  $^{23}\text{Na}$  und  $^{39}\text{K}$  als Ausnahme s. Text

Target	Anreicherungsgrad %	$(\gamma, p)$ -Schwelle MeV	Druck oder Dicke	Endenergie MeV	Zahl gemess. Protonen	Ausbeute $\mu\text{b}/\text{MeV sr}$	$\int \sigma(E) dE$	Figur
							MeVmb	
$^{18}\text{O}$	99	16,0	230 Torr	32,5	36074	$58 \pm 7$	$38 \pm 6$	1, 2
$^{20}\text{Ne}$	90,9	12,8	450 Torr	28,0	3175	$7,4 \pm 1$	—	—
			610 Torr	32,5	6293	$14,9 \pm 2$	$61 \pm 11$	5, 6
$^{22}\text{Ne}$	99,9	15,3	240 Torr	24,0	1960	$2,3 \pm 0,4$	—	4, 5
				28,0	4790	$3,6 \pm 0,6$	—	4, 5
				32,5	5210	$6,7 \pm 0,9$	$45 \pm 8$	4, 5
$^{23}\text{Na}$	100	8,8	65 $\mu$	24,0	14182	$6,3 \pm 1,0$	—	7
			60 $\mu$	32,5	11152	$12,8 \pm 2,0$	$117 \pm 30$	7
$^{36}\text{Ar}$	99	8,5	250 Torr	32,5	45173	$57 \pm 6$	$270 \pm 40$	8, 10
$^{40}\text{Ar}$	99,6	12,5	230 Torr	32,5	29559	$14,2 \pm 15$	$104 \pm 15$	9, 11
$^{39}\text{K}$	93,1	6,4	80 $\mu$	24,0	24230	$17,4 \pm 2,8$	—	12
			90 $\mu$	32,5	24941	$41,9 \pm 6,7$	$405 \pm 100$	12
$^{84}\text{Kr}$	99	10,7	170 Torr	32,5	35515	$12,7 \pm 2,0$	$80 \pm 20$	14
Kr	natürl.	10	170 Torr	32,5	13570	$12,5 \pm 2,0$	$75 \pm 20$	13
Xe	natürl.	9	150 Torr	32,5	7553	$7,6 \pm 0,9$	$40 \pm 7$	15

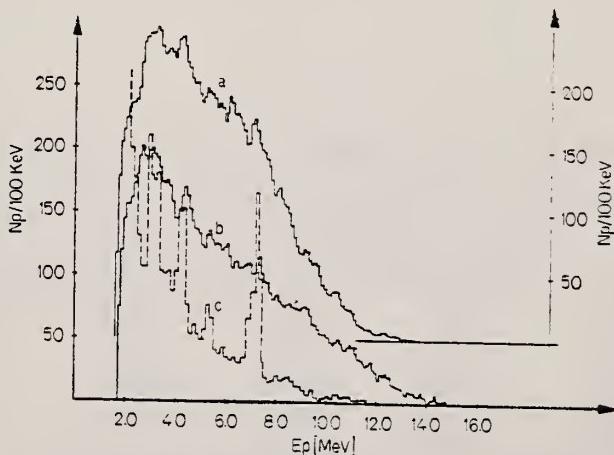


Fig. 7. Energiedichte der Photoprotonen aus  $^{23}\text{Na}$ . a Für  $E_0 = 24$  MeV,  
 b für  $E_0 = 32,5$  MeV, c nach OPHEL und WRIGHT [29]

METHOD

REF. NO.

69 Sa 3

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,E/	FMF	2 (2.08)	D	99-227	MAG-D	99-227	DST

B(EL) 2.08 MEV

Squared form factors for inelastic scattering of electrons with excitation of levels in  $^{23}\text{Na}$  and  $^{39}\text{K}$

2.08 MeV $^{23}\text{Na}$		3.6 MeV $^{39}\text{K}$		6.5 MeV $^{39}\text{K}$	
$q^2, \text{fermi}^{-2}$	$F_\lambda^2, 10^{-4}$	$q^2, \text{fermi}^{-2}$	$F_\lambda^2, 10^{-4}$	$q^2, \text{fermi}^{-2}$	$F_\lambda^2, 10^{-4}$
0.41	13.9 ± 13.9	0.72	7.43 ± 7.95	0.41	77.5 ± 22.9
0.51	26.3 ± 18.7	0.72	4.18 ± 11.12	0.52	45.4 ± 14.1
0.61	24.2 ± 14.7	0.32	10.9 ± 5.5	0.62	43.1 ± 15.1
0.71	32.4 ± 9.4	0.91	18.5 ± 3.3	0.72	23.9 ± 5.7
0.71	22.0 ± 10.3	0.91	14.6 ± 4.4	0.72	23.0 ± 7.8
0.80	45.8 ± 10.8	0.92	12.0 ± 3.3	0.82	18.2 ± 4.1
0.90	70.3 ± 9.1	1.01	18.4 ± 2.4	0.91	6.7 ± 2.0
0.90	31.0 ± 8.9	1.10	24.7 ± 2.4	0.91	11.4 ± 2.8
0.99	46.3 ± 5.0	1.19	18.9 ± 1.7	0.92	9.2 ± 2.4
1.08	31.2 ± 2.9	1.28	17.0 ± 1.7	1.01	7.5 ± 1.9
1.17	20.8 ± 1.7	1.37	11.8 ± 1.2	1.10	6.3 ± 1.5
1.26	14.5 ± 1.2	1.44	8.66 ± 0.87	1.28	4.45 ± 1.09
1.35	11.1 ± 0.9	1.53	5.50 ± 0.75	1.37	3.73 ± 0.58
1.41	7.46 ± 0.67	1.61	4.56 ± 0.32	1.44	2.77 ± 0.57
1.45	7.20 ± 0.50	1.73	1.35 ± 0.35		
1.48	5.32 ± 0.31				
1.51	5.71 ± 0.43				
1.54	4.43 ± 0.35				
1.73	1.37 ± 0.15				
1.86	1.11 ± 0.14				
1.98	0.91 ± 0.12				
2.08	1.07 ± 0.20				

Table 4

Characteristics of transitions excited by high-energy electrons in  $^{23}\text{Na}$  and  $^{39}\text{K}$

Method	Parameters and method of determination	2.08 MeV $^{23}\text{Na}$ ( $\lambda=2$ )	3.6 MeV $^{39}\text{K}$ ( $\lambda=3$ )	6.5 MeV $^{39}\text{K}$ ( $\lambda=1$ )
1	$3_\lambda, 10^{-2}$	$11.6 \pm 2.5$	$13.1 \pm 2.8$	$3.40 \pm 0.69$
	$B(E\lambda, I_i \rightarrow I_f) e^2 \text{ fermi}^{2\lambda}$	$107 \pm 23$	$11800 \pm 2500$	$14.3 \pm 2.9$
2	$G$	$13.7 \pm 3.0$	$19 \pm 4$	$6.4 \pm 1.3$
	$A_\lambda, \text{ fermi}^{\lambda-2}$	$1.55 \pm 0.10$	$1.39 \pm 0.04$	$1.79 \pm 0.15$
	$B_\lambda, \text{ fermi}^2$	$0.45 \pm 0.07$	$0.34 \pm 0.09$	$0.79 \pm 0.17$
	$B(E\lambda, I_i \rightarrow I_f), e^2 \text{ fermi}^{2\lambda}$	$80 \pm 11$	$6300 \pm 400$	$8.5 \pm 1.5$
	$G$	$10.2 \pm 1.4$	$10 \pm 1$	$3.8 \pm 0.7$
	$R_{\text{trans}}, \text{ fermi}$	$3.93 \pm 0.57$	$4.38 \pm 0.06$	$3.80 \pm 0.22$

METHOD	REF. NO.					
	70 Sh 2				egf	
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR	ANGLE
			TYPE	RANGE	TYPE	
G,G	LFT	7	C	14	SCD-D	

7 = 7.895 MEV

Table 1  
Comparison between experimental  $\log f\tau$  values and radiative widths:  $\Gamma_{th}$  represents the width estimated only from the spin part with eq. (1);  $R$  denotes the ratio of the reduced matrix element of the spin part to that of the orbital part.

$E_i$ (keV)	$(T, J^\pi)$	$E_f$ (keV)	$(T, J^\pi)$	$\log f\tau$	$\Gamma_{th}$ (eV)	$\Gamma_{obs}$ (eV) <sup>a)</sup>	$R$
23Na	7895	$(\frac{1}{2}, \frac{1}{2}^+)$	0	$(\frac{1}{2}, \frac{1}{2}^+)$	5.3	0.21	$1.02 \pm 0.37$
23Na	7895	$(\frac{1}{2}, \frac{1}{2}^+)$	439	$(\frac{1}{2}, \frac{1}{2}^+)$	5.4	0.14	$0.57 \pm 0.21$
31P	6381	$(\frac{1}{2}, \frac{1}{2}^+)$	0	$(\frac{1}{2}, \frac{1}{2}^+)$	5.5	0.07	$\leq 0.11$

a) In the estimate of  $\Gamma_{obs}$ , the branching ratio  $\Gamma_0/\Gamma$  for 23Na and 31P were assumed to be 0.64 and 0.18, respectively.

METHOD

REF. NO.

71 Al 1

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N 347	ABX	12-27	D	12-27	BF3-I		4PI *
G, 2N 350+	ABX	23-27	D	23-27	BF3-I		4PI

\* INCLUDES G, NP 347

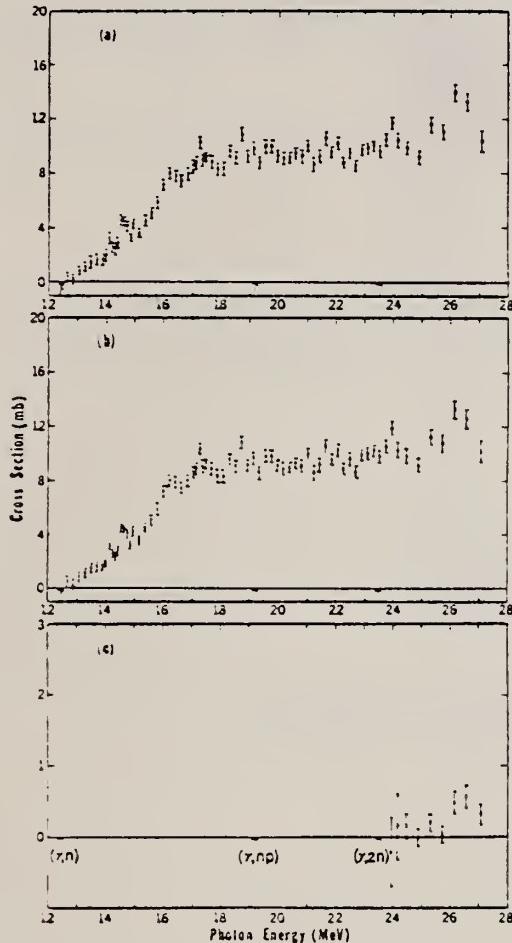


FIG. 2. Cross sections for  $^{23}\text{Na}$ . (a) Total photon-neutron cross section,  $\sigma[(\gamma, n) + (\gamma, np) + (\gamma, 2n)]$ . (b) Single-photon-neutron cross section,  $\sigma[(\gamma, n) + (\gamma, np)]$ . (c) Double-photon-neutron cross section,  $\sigma(\gamma, 2n)$ . The thresholds (arrows, are taken from Mattauch *et al.* (see Table I).

TABLE II. Integrated total photoneutron cross sections and their moments.

Nucleus	$E_{\gamma}^{\max}$ (MeV)	$\sigma_{\text{int}}^a$ (MeV mb)	$\sigma_{-1}^b$ (mb)	$\sigma_{-2}^b$ (mb MeV $^{-1}$ )
$^{23}\text{Na}$	27	119	5.74	0.288
$^{25}\text{Mg}$	29	249	11.7	0.584

<sup>a</sup>  $\sigma_{\text{int}} \equiv \int_{E_{\text{thr}}}^{E_{\gamma}^{\max}} \sigma_{\text{tot}} dE$ .

<sup>b</sup>  $\sigma_{-n} \equiv \int_{E_{\text{thr}}}^{E_{\gamma}^{\max}} \sigma_{\text{tot}} E^{-n} dE$ .

(over)

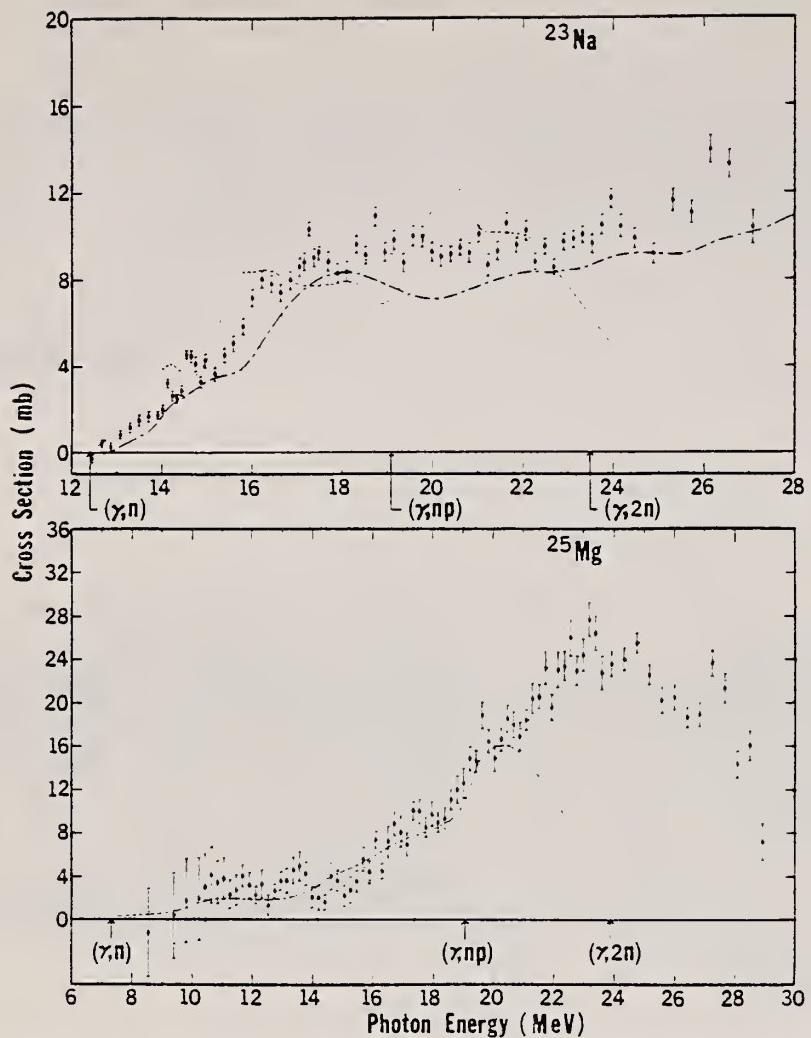


FIG. 4. Comparison of the present total photoneutron cross sections with previous measurements. The dashed curves indicate the results of Sato (Ref. 11) for  $^{23}\text{Na}$  and of Nathans and Yergin (Ref. 13) for  $^{25}\text{Mg}$ ; the dash-dot curve represents the  $^{23}\text{Na}$  data of Fielder, Bolen, and Whitehead (Ref. 12).

METHOD	REF. NO.					
	71 Pi 2					
	egf					
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR		ANGLE
			TYPE	RANGE	TYPE	
P,G	RLX	9-10	D	0-2	SCD-D	DST

9.61 MEV LEVEL, J-PI

Table. Angular distribution coefficients and mixing ratios measured at the  $E_p = 853$  keV

$E_i$ (MeV)	$J_i^P$	$E_f$ (MeV)	$J_f^P$	Legendre polynomial coefficients		$\delta$
				$a_2$	$a_4$	
9.61	$3/2^+$	0	$3/2^+$	$0.60 \pm 0.04$	$-0.04 \pm 0.04$	$0.15 \pm 0.07$
		0.44	$5/2^+$	$-0.18 \pm 0.01$	$0.00 \pm 0.01$	$2.2 \pm 0.4$
		3.91	$5/2^+$	$-0.16 \pm 0.02$	$-0.01 \pm 0.02$	$0.07 \pm 0.06$
3.91	$5/2^+$	0	$3/2^+$	$0.00 \pm 0.02$	$0.00 \pm 0.02$	$-7.0 \pm 1.5$
						$0.05 \pm 0.05$
						$-6.0 \pm 1.5$
						$-0.20 \pm 0.08$
						$10.0 \pm 2.0$

$E_p$ (keV)	$E_\gamma$ (keV)	$^{22}\text{Ne}(p,\gamma)^{23}\text{Na}$	$J^*$	$\gamma$ (keV)
12.79	10016	-2-15-5 33-12-8-23 -1-1 -1 2	5/2 <sup>+</sup>	100
261	00000	-18 -1-49 4 -5 -13	1/2 <sup>-</sup>	8
174	9917	-5-14 1 23-34 -24	(3/2, 5/2) <sup>*</sup>	
147	9897	-23-19 8-18 -1-9-2	(3/2) <sup>*</sup>	2
105	9851	-7 31-32 3-3 -4	1/2 <sup>+</sup>	29
109	9838	-43-3-12 5-5-7	3/2 <sup>+</sup>	36
1069	2817	-10-9-18 7-3 7-3 2-8 5	1/2 <sup>-</sup>	3
1006	9756	-9-9 54 2-10-6	3/2 <sup>+</sup>	38
982	9733	-21-3 9 2-7 4-5 -5	7/2 <sup>-</sup>	5
950	9703	-42-25-2-9 5-9 3 -3	3/2 <sup>+</sup>	62
329	9683	-26-3 -8-13-35-5	(23/2, 5/2) <sup>*</sup>	3
921	9675	-15-34-18 -10-4-2-10	6	5/2 <sup>+</sup>
900	9554	-48 -1-3 48	1/2 <sup>+</sup>	4
897	9552	-30-44-1 3 -20 -2	5/2 <sup>+</sup>	32
953	9510	-27-42 2 3 -2-21 -3	3/2 <sup>+</sup>	105
726	9488	-34-42 -8 6	(3/2) <sup>*</sup>	2
662	9423	-6-2 -4 -7-9-5	3/2 <sup>+</sup>	6
642	9406	-7-2 3 -9-8 -4	1/2 <sup>-</sup>	54
480	9353	-48 -5-6 39 -2	2, 3/2 <sup>+</sup>	3

Fig. 1. Decay modes of the excited states in  $^{23}\text{Na}$  proposed in the present work. The  $J^*$  assignments are from Refs. <sup>1,9</sup>, except those marked with an asterisk, which are from the present work (see discussion). Errors in  $E_\gamma$  values are  $\pm 2$  keV.

(over)

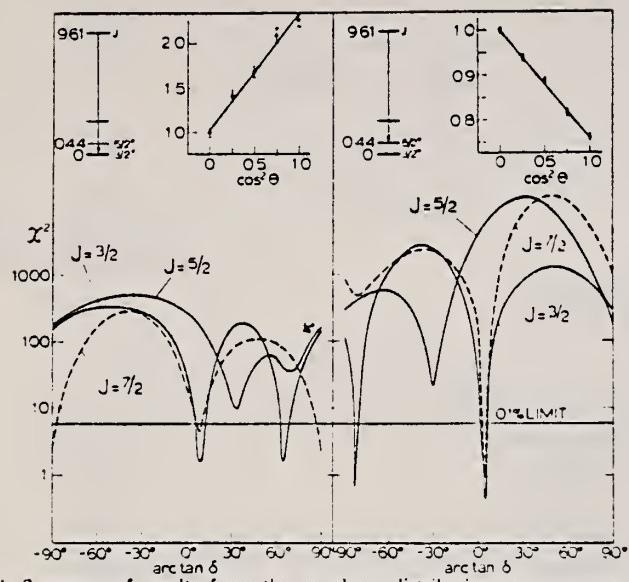


Fig. 4. Summary of results from the angular  $\gamma$ -distribution measurements of the  $9.61 \rightarrow 0$  and  $9.61 \rightarrow 0.44$  MeV transitions from the  $E_p = 853$  keV resonance

METHOD

REF. NO.

71 Sa 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N	ABY	12-68	C	10-68	ACT-I		4PI

Nippon Kagaku Zasshi, 92, 164~168(1971)

The Yields of Radioactivities Induced by  $(\gamma, n)$  Reactions with Bremsstrahlung up to 68 MeV

by Tatsuya SAITO

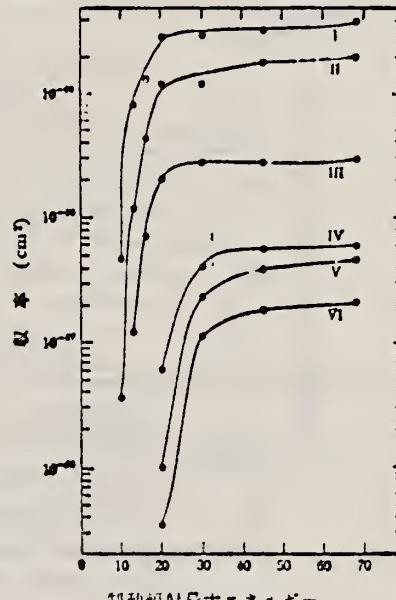
The  $(\gamma, n)$  yields of 12 target nuclides have been measured at 10, 13, 16, 30, 45 and 68 MeV bremsstrahlung by observing the induced activities.

The energy dependence of the yields has been investigated extensively in the same way as in the previous work at 20 MeV bremsstrahlung.

In the case of heavy nuclides, the yields rise greatly as a function of maximum bombarding energy up to 20 MeV, and rise gradually from 20 MeV up to 68 MeV. However, in the case of light nuclides, the yields rise greatly up to 30 MeV, because the neutron separation energies of light ones are larger than those of heavy ones, and the bremsstrahlung spectrum covers the giant resonance and so the yields rise gradually from 30 MeV up to 68 MeV.

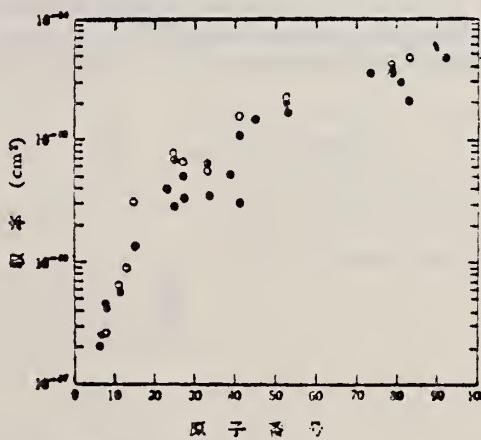
The yields have approximately been estimated from the parameter of the giant resonance, that is the peak cross section and the half width, in order to compare with the experimental data. As a result, the experimental data of light nuclides and heavy ones are nearly in agreement with the estimated data of Nathans et al., Julins et al. and Montalbetti et al., but those of medium weight ones are relatively lower values.

Department of Chemistry, Faculty of Science, Tohoku University; Katahira-cho, Sendai-shi, Japan



制動輻射最大エネルギー

I:  $^{197}\text{Au}(\gamma, n)^{196}\text{Au}$ , II:  $^{137}\text{I}(\gamma, n)^{134}\text{I}$   
 III:  $^{54}\text{Mn}(\gamma, n)^{54}\text{Mn}$ , IV:  $^{22}\text{Na}(\gamma, n)^{22}\text{Na}$   
 V:  $^{16}\text{O}(\gamma, n)^{16}\text{O}$ , VI:  $^{12}\text{C}(\gamma, n)^{12}\text{C}$

図 3  $(\gamma, n)$  反応の収率

●: 実験値, ○: Johns ら,  
 ◎: Nathans ら, □: Montalbetti ら

図 4  $(\gamma, n)$  反応の収率の比較

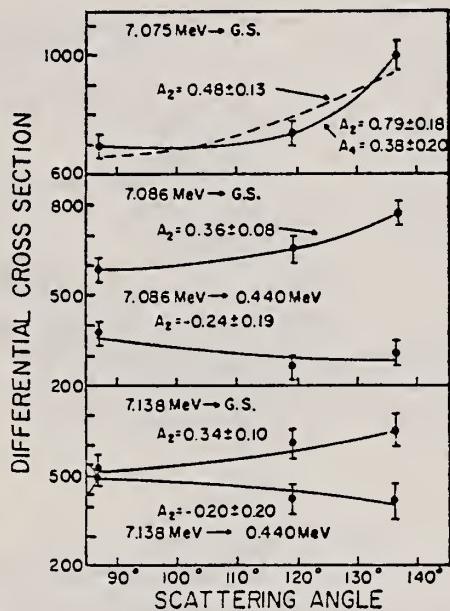
METHOD

REF. NO.

71 Sw 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G <sub>1</sub> G	LFT	7	D	7	SCD-D		DST



5 LEVELS

Fig. 3. Results of angular distribution measurements. The curves drawn were the least-square fits with the  $A_2$  and/or  $A_4$  coefficients given.

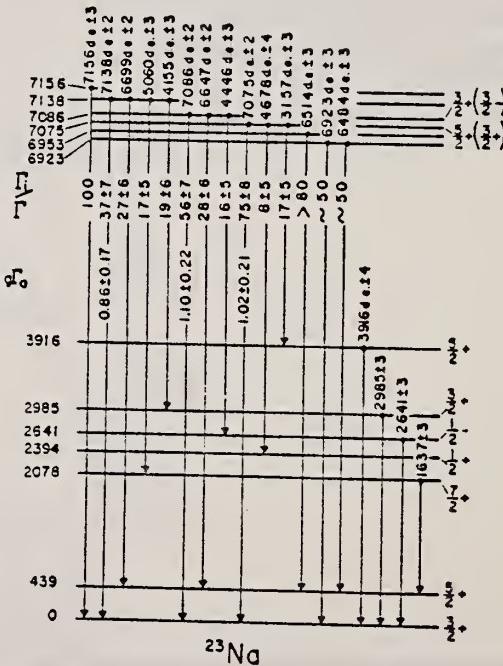


Fig. 2. Level scheme of observed  $\gamma$ -rays. The d.e. indicates that the double-escape peak was used in obtaining the energy. Given also are the branching ratios and some widths in eV for the ground state transitions. The spins and parities for the levels from 3.916 down were taken from Poletti *et al.*<sup>7</sup> and Maier *et al.*<sup>8</sup>.

## METHOD

REF. NO.

72 Fr 4

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	3-6	C	3-6	NAI-D		130

## G-WIDTH, 5 LEVELS

Five levels in  $^{23}\text{Na}$  were studied using nuclear resonance fluorescence. A previously reported level at 3.91 MeV was identified as a doublet with levels at  $3914.0 \pm 1.8$  and  $3916.3 \pm 1.8$  keV. Levels of  $5375.8 \pm 2.7$ ,  $5742.7 \pm 2.9$ , and  $5768.3 \pm 2.9$  keV have widths ( $g\Gamma$ ) of  $2.45^{+0.41}_{-0.41}$ ,  $1.29^{+0.19}_{-0.19}$ , and  $0.62^{+0.35}_{-0.34}$  eV, respectively, as measured by self-absorption experiments. The  $\gamma$ -ray branching ratios for these levels were measured with a  $40-\text{cm}^3$  Ge(Li) spectrometer.

TABLE I. Experimental results.

Energy level (keV)	Transition (keV)	Branching ratio (present work)	Branching ratio (other work) <sup>a</sup>	Transmission $\Gamma=0^b$	Transmission experimental	Possible spin	$g\Gamma$ (meV)
$3914.0 \pm 1.8$	3914		0.81	0.730	$0.685 \pm 0.058$	$(\frac{1}{2})^+$	$28 \pm 27$
$3916.3 \pm 1.8$	3918		0.81	0.730	$0.622 \pm 0.054$	$(\frac{1}{2})^+$	$49 \pm 27$
$5375.8 \pm 2.7$	5378	$0.12 \pm 0.08$	$0.14 \pm 0.04$	0.780	$0.484 \pm 0.029$	$(\frac{1}{2})^+$	$2450^{+40}_{-40}$
	4935	$0.69 \pm 0.15$	$0.63 \pm 0.07$				
	3297	$0.19 \pm 0.07$	$0.23 \pm 0.05$				
$5742.7 \pm 2.9$	5743	$0.71 \pm 0.13$	$0.60 \pm 0.10$	0.766	$0.298 \pm 0.012$	$(\frac{1}{2}, \frac{3}{2})^+$	$1400^{+170}_{-130}, 1290^{+160}_{-130}$
	5302	$0.29 \pm 0.05$	$0.40 \pm 0.10$				
$5768.3 \pm 2.9$	5768	$0.73 \pm 0.15$		0.767	$0.395 \pm 0.029$	$(\frac{1}{2})^c$	$800^{+120}_{-120}$
	5327	$0.27 \pm 0.13$					

<sup>a</sup> Branching ratios and spins reported by Poletti et al. (Refs. 1, 2, 8).<sup>b</sup> Expected transmission if only electronic absorption were present (no resonant absorption).<sup>c</sup> Spin of  $\frac{1}{2}$  arbitrarily chosen to allow comparison with other widths.

<sup>1</sup> A.R. Poletti and D.F.H. Start, Phys. Rev. 147, 800 (1966).

<sup>2</sup> A.R. Poletti, J.A. Becker, and R.E. McDonald, Phys. Rev. C2, 964 (1970).

<sup>8</sup> A.R. Poletti et al., Phys. Rev. 184, 1130 (1969).



METHOD

REF. NO.

72 Sh 2

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G/	SPC	0-14	C	14	SCD-D		87

TABLE 2  
 Gamma-rays resulting from the photon bombardment of a NaOH target

$E_{\gamma}$ (MeV)	Observed peak	Relative intensity	Transition
2.98	F	19 ± 7	2.98 → 0
4.43	D, S, F	89 ± 4	4.43 → 0
4.94	D, S, F	14.7 ± 1.5	5.38 → 0.44
5.30	D, S, F	7.7 ± 1.6	5.74 → 0.44
5.33	D, S, F	6.3 ± 1.6	5.77 → 0.44
5.74	D, S, F	27.3 ± 1.2	5.74 → 0
5.77	D, S, F	15.1 ± 1.2	5.77 → 0
6.30	(D)	3.4 ± 0.8	8.37 → 2.07
6.64	(D)	3.4 ± 1.0	7.09 → 0.44
6.70	D, (S)	2.8 ± 0.9	7.14 → 0.44
6.74	D, S, (F)	8.6 ± 0.9	6.74 → 0
7.07	D, (S), F	10.8 ± 0.7	7.07 → 0
7.09	D, S, F	9.3 ± 0.7	7.09 → 0
7.14	D, S, (F)	11.5 ± 0.8	7.14 → 0
7.46	D, S, F	10.6 ± 0.8	7.90 → 0.44
7.57	D, (S)	2.7 ± 0.7	7.57 → 0
7.90	D, S, F	18.5 ± 0.8	7.90 → 0
7.93	(D), (S)	7.3 ± 0.7	8.37 → 0.44
8.37	D, S	12.0 ± 0.7	8.37 → 0
8.65	D	6.5 ± 0.6	8.65 → 0
8.67	D, S	12.7 ± 0.6	8.67 → 0
9.15	D	7.5 ± 0.6	9.15 → 0

(over)

TABLE 6

Excitation energies and ground state transition widths obtained from the  $^{23}\text{Na}(\gamma, \gamma')^{23}\text{Na}$  reaction

Excitation energy (keV)		$J^\pi; T$	$\Gamma_{\gamma 0}/\Gamma_\gamma$ <sup>a)</sup>	$(2J+1)\Gamma_{\gamma 0}$ (eV) <sup>b)</sup>	
present work	previous work			present work	previous work
2979 $\pm$ 6	2985 $\pm$ 6 <sup>c)</sup>	( $\frac{3}{2}^+$ )	<sup>c)</sup>	0.51 <sup>c)</sup>	0.20 $\pm$ 0.08 <sup>c)</sup>
4426 $\pm$ 4	4431 $\pm$ 5 <sup>c)</sup>	$\frac{1}{2}^+$	<sup>d)</sup>	0.95 <sup>d)</sup>	5.0 $\pm$ 0.8 <sup>d)</sup>
5376 $\pm$ 4	5378 $\pm$ 5 <sup>c)</sup>	$\frac{3}{2}^+$	<sup>e)</sup>	0.13 $\pm$ 0.01 <sup>e)</sup>	1.6 $\pm$ 0.3 <sup>e)</sup>
5744 $\pm$ 4	5738 $\pm$ 8 <sup>c)</sup>	( $\frac{1}{2}, \frac{3}{2}$ ) <sup>f)</sup>	<sup>h)</sup>	0.78 $\pm$ 0.04	3.7 $\pm$ 0.7
5768 $\pm$ 4	5762 $\pm$ 8 <sup>c)</sup>			0.70 $\pm$ 0.06	2.1 $\pm$ 0.4
6739 $\pm$ 4	6731 $\pm$ 8 <sup>c)</sup>	( $\frac{1}{2}, \frac{3}{2}$ ) <sup>g)</sup>	<sup>i)</sup>	1.0	1.5 $\pm$ 0.3
7074 $\pm$ 5	7075 $\pm$ 2 <sup>j)</sup>	$\frac{3}{2}^+$	<sup>j)</sup>	1.0	3.0 $\pm$ 0.5 <sup>k)</sup>
7086 $\pm$ 5	7086 $\pm$ 2 <sup>j)</sup>	$\frac{3}{2}^+$	<sup>j)</sup>	0.75 $\pm$ 0.06 <sup>j)</sup>	3.4 $\pm$ 0.7 <sup>k)</sup>
7137 $\pm$ 5	7138 $\pm$ 2 <sup>j)</sup>	( $\frac{1}{2}, \frac{3}{2}, \frac{5}{2}$ ) <sup>j)</sup>		0.80 $\pm$ 0.05	3.8 $\pm$ 0.7 <sup>k)</sup>
7572 $\pm$ 6	7563 $\pm$ 7 <sup>c)</sup>			1.0	0.7 $\pm$ 0.2
7896 $\pm$ 5	7900 $\pm$ 21 <sup>m)</sup>	$\frac{3}{2}^+, T = \frac{1}{2}$ <sup>m)</sup>		0.67 $\pm$ 0.02 <sup>i)</sup>	11 $\pm$ 2
8367 $\pm$ 5	8357 $\pm$ 8 <sup>c)</sup>	( $\frac{1}{2}, \frac{3}{2}$ )		0.53 $\pm$ 0.03 <sup>n)</sup>	12 $\pm$ 2
8652 $\pm$ 6	8643 $\pm$ 7 <sup>c)</sup>			1.0	3.1 $\pm$ 0.6
8669 $\pm$ 5	8659 $\pm$ 30 <sup>d)</sup>	$\frac{1}{2}^+, T = \frac{1}{2}$ <sup>d)</sup>		1.0	6.5 $\pm$ 1.1
9147 $\pm$ 5				1.0	5.2 $\pm$ 0.9 <sup>o)</sup>

<sup>a)</sup> The branchings are obtained from the relative intensities observed at the scattering angle of 87°. The effect of the angular distribution of the  $\gamma$ -rays is not taken into account.

<sup>b)</sup> The error for  $(2J+1)\Gamma_{\gamma 0}$  only includes the statistical error. An estimate of the uncertainty associated with the shape of the incident bremsstrahlung is not included.

<sup>c)</sup> Ref. <sup>8)</sup>.

<sup>d)</sup> Ref. <sup>18)</sup>.

<sup>e)</sup> Ref. <sup>19)</sup>.

<sup>f)</sup> Ref. <sup>51)</sup>.

<sup>g)</sup> Ref. <sup>52)</sup>.

<sup>h)</sup> Ref. <sup>53)</sup>.

<sup>i)</sup> Ref. <sup>8)</sup>. The energy of the state is given as 6727 $\pm$ 20 keV in ref. <sup>9)</sup>.

<sup>j)</sup> Ref. <sup>20)</sup>.

<sup>k)</sup> This value is calculated by using the result of the angular distribution measurement given in ref. <sup>20)</sup>.

<sup>l)</sup> This value is calculated on the assumption that the transitions to lower states are of pure dipole character.

<sup>m)</sup> Ref. <sup>17)</sup>.

<sup>n)</sup> The 8.37 MeV state decays to three lower states. The branching to the 0.44 and 2.07 MeV states are 0.32 $\pm$ 0.03 and 0.15 $\pm$ 0.03, respectively.

<sup>o)</sup> The value given is not the  $(2J+1)\Gamma_{\gamma 0}$  but the  $(2J+1)\Gamma_{\gamma 0}/\Gamma$  value.

<sup>8</sup>P.M. Endt et al. Nucl. Phys. A105 (1967) 1.

<sup>17</sup>J.C. Hardy et al. Phys. Rev. 183 (1969) 854.

<sup>18</sup>J. Dubois, Nucl. Phys. A104 (1967) 657.

<sup>19</sup>H.J. Hay et al. Nucl. Phys. A98 (1967) 330.

<sup>20</sup>C.P. Swann, Nucl. Phys. A167 (1971) 201.

<sup>51</sup>E. Kramer et al. Nucl. Phys. A165 (1971) 353.

<sup>52</sup>M.F. da Silva et al. Nucl. Phys. A168 (1971) 663.

<sup>53</sup>A.R. Poletti et al. Phys. Rev. 184 (1969) 1130.

METHOD

REF. NO.

72 To 3

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,MU-T	LFT	9	D	9	NAI-D		4PI

9.404, 9.700 MEV

Gamma rays of energy 9.404 and 9.700 MeV were obtained from the reaction  $^{22}\text{Ne}(p, \gamma)^{23}\text{Na}$  at proton energies of 640 and 950 keV respectively and were resonantly absorbed in sodium metal. Isotopically separated  $^{22}\text{Ne}$  targets on nickel backings were used. The following level widths for  $^{23}\text{Na}$  were obtained:

The 9.404 MeV level:

$$\Gamma = 65 \pm 40 \text{ eV}$$

$$\Gamma_\gamma = 2.2 \pm 0.7 \text{ eV.}$$

The 9.700 MeV level:

$$\Gamma = 9.5 \begin{array}{l} +4.5 \\ -1.0 \end{array} \text{ eV}$$

$$\Gamma_\gamma = 5.6 \begin{array}{l} +1.2 \\ -0.8 \end{array} \text{ eV.}$$

The disagreement between the results for the 9.404 MeV level and the previously determined values can probably be ascribed to proton scattering in the window of the gas target used in the latter measurement.



METHOD

REF. NO.

72 Vi 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P,G	NOX	9-10	D	0-1	SCD-D		DST

4 LEVELS, J-PI

Table 1. Experimental angular distribution coefficients

Resonance	Transition	$a_2$	$a_4$
$E_p = 897 \text{ keV}$	$r \rightarrow 0$	$0.68 \pm 0.08$	$0.12 \pm 0.08$
$E_x = 9652 \text{ keV}$	$r \rightarrow 440$	$0.74 \pm 0.06$	$0.06 \pm 0.06$
	$r \rightarrow 4775$	$-0.05 \pm 0.05$	$-0.09 \pm 0.07$
	$4775 \rightarrow 440$	$0.18 \pm 0.06$	$-0.17 \pm 0.07$
	$4775 \rightarrow 2076$	$0.33 \pm 0.14$	$0.02 \pm 0.13$
$E_p = 1006 \text{ keV}$	$r \rightarrow 0$	$0.22 \pm 0.05$	$-0.10 \pm 0.06$
$E_x = 9756 \text{ keV}$	$r \rightarrow 440$	$-0.22 \pm 0.04$	$0.07 \pm 0.05$
	$r \rightarrow 2640$	$-0.44 \pm 0.02$	$0.01 \pm 0.03$
	$r \rightarrow 3678$	$0.41 \pm 0.04$	$-0.03 \pm 0.04$
	$r \rightarrow 3846$	$0.12 \pm 0.05$	$0.03 \pm 0.06$
	$3846 \rightarrow 2076$	$-0.23 \pm 0.04$	$0.02 \pm 0.04$
	$3678 \rightarrow 440$	$0.07 \pm 0.03$	$-0.08 \pm 0.03$
	$2640 \rightarrow 0$	$0.00 \pm 0.02$	$-0.03 \pm 0.03$
$E_p = 1091 \text{ keV}$	$r \rightarrow 0$	$0.72 \pm 0.04$	$0.00 \pm 0.03$
$E_x = 9838 \text{ keV}$	$r \rightarrow 440$	$-0.16 \pm 0.05$	$-0.09 \pm 0.05$
	$r \rightarrow 2391$	$-0.06 \pm 0.05$	$-0.06 \pm 0.06$
	$r \rightarrow 3913$	$-0.06 \pm 0.10$	$0.02 \pm 0.11$
	$r \rightarrow 4430$	$-0.14 \pm 0.07$	$0.02 \pm 0.08$
	$4430 \rightarrow 0$	$0.01 \pm 0.08$	$0.08 \pm 0.09$
	$3913 \rightarrow 0$	$-0.08 \pm 0.06$	$0.03 \pm 0.07$
	$2391 \rightarrow 440$	$0.05 \pm 0.06$	$-0.01 \pm 0.07$
	$2391 \rightarrow 0$	$0.05 \pm 0.05$	$-0.03 \pm 0.06$
$E_p = 1278 \text{ keV}$	$r \rightarrow 0$	$-0.64 \pm 0.08$	$0.40 \pm 0.10$
$E_x = 10016 \text{ keV}$	$r \rightarrow 440$	$0.22 \pm 0.03$	$0.01 \pm 0.03$
	$r \rightarrow 2076$	$0.27 \pm 0.04$	$-0.02 \pm 0.04$
	$r \rightarrow 2983$	$-0.43 \pm 0.02$	$0.00 \pm 0.02$
	$r \rightarrow 3678$	$-0.40 \pm 0.02$	$0.03 \pm 0.03$
	$r \rightarrow 3846$	$0.36 \pm 0.07$	$0.01 \pm 0.07$
	$r \rightarrow 3913$	$0.51 \pm 0.03$	$-0.03 \pm 0.03$
	$r \rightarrow 6617$	$0.25 \pm 0.13$	$0.14 \pm 0.15$
	$6617 \rightarrow 440$	$-0.07 \pm 0.06$	$-0.16 \pm 0.07$
	$3913 \rightarrow 0$	$-0.05 \pm 0.02$	$0.01 \pm 0.02$
	$3846 \rightarrow 2076$	$-0.03 \pm 0.06$	$-0.01 \pm 0.07$
	$3678 \rightarrow 440$	$-0.05 \pm 0.02$	$0.03 \pm 0.03$
	$3678 \rightarrow 2640$	$-0.58 \pm 0.03$	$-0.01 \pm 0.04$
	$2983 \rightarrow 0$	$0.44 \pm 0.04$	$-0.04 \pm 0.04$
	$2983 \rightarrow 440$	$-0.19 \pm 0.04$	$0.06 \pm 0.04$

$$W(\theta) = 1 + a_2 P_2 + a_4 P_4$$

(over)

**Table 2.** Multipole mixing ratios  $\delta$  of the primary gamma-rays from the resonance levels measured in the present investigation

Resonance	Transition ( $E_x$ in keV)	$J_i \rightarrow J_f$	Mixing ratio $\delta$
$E_p = 897$ keV $E_x = 9652$ keV	$r \rightarrow 0$	$5/2 \rightarrow 3/2$	$0.63 \pm 0.03$
	$r \rightarrow 440$	$5/2 \rightarrow 5/2$	$0.30 \pm 0.04$
$E_p = 1006$ keV $E_x = 9756$ keV	$r \rightarrow 4775$	$5/2 \rightarrow 7/2$	$-0.07 \pm 0.03$
	$r \rightarrow 0$	$3/2 \rightarrow 3/2$	$-0.11 \pm 0.02$
$E_p = 1091$ keV $E_x = 9838$ keV			$7.0 \pm 0.5$
	$r \rightarrow 440$	$3/2 \rightarrow 5/2$	$0.10 \pm 0.01$
			$-9.0 \pm 1.0$
	$r \rightarrow 2640$	$3/2 \rightarrow 1/2$	$0.04 \pm 0.02$
	$r \rightarrow 3678$	$3/2 \rightarrow 3/2$	$0.01 \pm 0.02$
			$3.9 \pm 0.4$
	$r \rightarrow 3846$	$3/2 \rightarrow 5/2$	$-0.19 \pm 0.04$
		$3/2 \rightarrow 7/2$	$0.03 \pm 0.02$
	$r \rightarrow 0$	$3/2 \rightarrow 3/2$	$0.25 \pm 0.02$
			$2.0 \pm 0.1$
$E_p = 1278$ keV $E_x = 10016$ keV	$r \rightarrow 440$	$3/2 \rightarrow 5/2$	$0.04 \pm 0.02$
			$-6.0 \pm 0.5$
	$r \rightarrow 2391$	$3/2 \rightarrow 1/2$	$0.24 \pm 0.06$
			$-3.2 \pm 0.5$
	$r \rightarrow 3913$	$3/2 \rightarrow 3/2$	$-0.28 \pm 0.03$
			$-18.0 \pm 3.0$
		$3/2 \rightarrow 5/2$	$-0.03 \pm 0.07$
			$-4.3 \pm 0.7$
	$r \rightarrow 4430$	$3/2 \rightarrow 1/2$	$0.19 \pm 0.03$
		$3/2 \rightarrow 3/2$	$-3.2 \pm 0.2$
			$-0.38 \pm 0.08$
			$-11.0 \pm 1.0$

ELEM. SYM.	A	Z
Na	23	11
REF. NO.	73 Ve 2	hmg

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P,G	ABX	14- 26	D	5- 18	NAI-D		90

$$G = G_0 + G_1$$

777

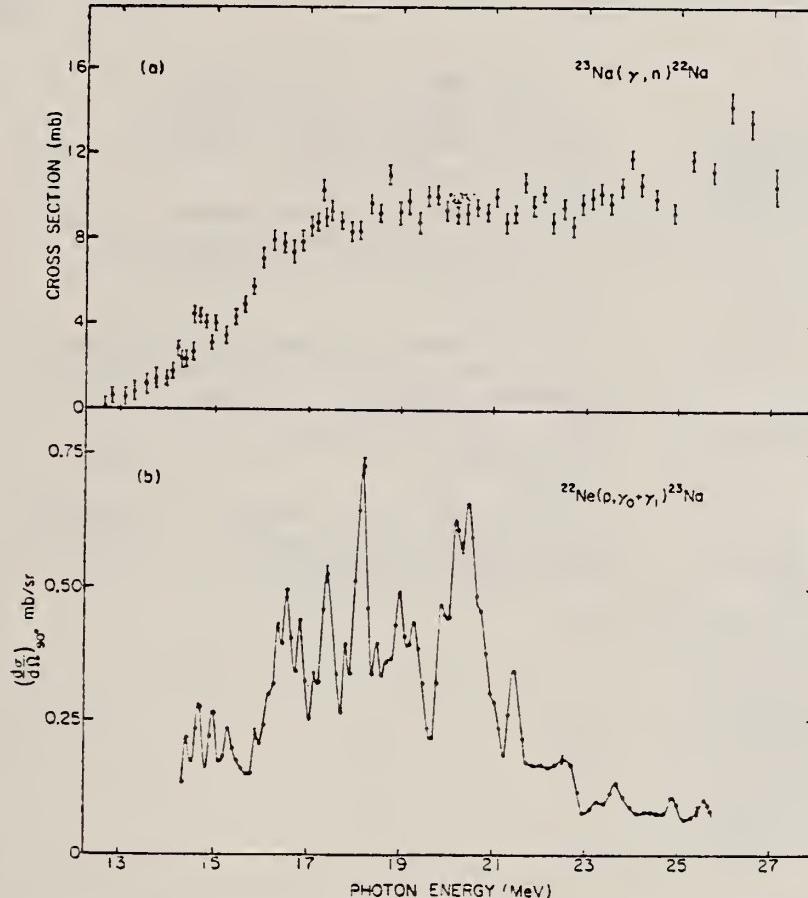


FIG. 2. (a) Photoneutron cross section for  $^{23}\text{Na}$  as measured by Alvarez *et al.* (Ref. 8). (b) Differential cross section as a function of photon energy for  $^{22}\text{Ne}(p, \gamma_0 + \gamma_1)^{23}\text{Na}$  at  $\theta_{lab} = 90^\circ$ . The yield curve has been converted to a photodisintegration curve (in the conversion  $E_{\gamma_0}$  is used for the photon energy).

The differential cross section for the capture reaction  $^{22}\text{Ne}(p, \gamma_0 + \gamma_1)^{23}\text{Na}$  has been measured. Significant structure is observed in the giant-resonance region. Comparison with the reaction  $^{23}\text{Na}(\gamma, n)^{22}\text{Ne}$  indicates a splitting of the dipole strength. Possible sources of this splitting are discussed.

## METHOD

REF. NO.

74 Di 7

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, 3P3N	ABY	THR* 1	C	300* 1	ACT-I		4PT

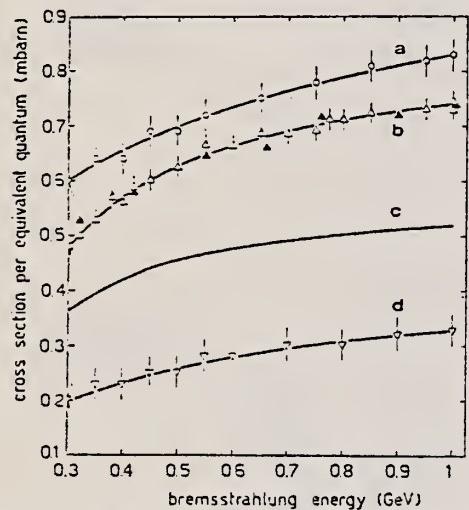
l=1 GEV

Fig. 1. Cross section per equivalent quantum  $\sigma_Q$  vs the bremsstrahlung maximum energy. Curve a is an eye-fit of the present work values (open circles) for the reaction  $^{23}\text{Na}(\gamma, 2p\ 3n)^{19}\text{F}$ . Curve b is an eye-fit of the present work values (open triangles) and the values taken from Ref. [2] (filled triangles) for the reaction  $^{27}\text{Al}(\gamma, 2p\ 3n)^{22}\text{Na}$ . Curve c is the best-fit of the present work values and values taken from Refs. [18, 20-22] for the reaction  $^{12}\text{C}(\gamma, 2p\ 3n)^{7}\text{Be}$ ; for the sake of simplicity, experimental points have not been reported. Curve d is an eye-fit of the present work values (reversed open triangles) for the reaction  $^{16}\text{O}(\gamma, 2p\ 3n)^{11}\text{C}$ .

<sup>2</sup>V. di Napoli, A.M. Lacerenza, F. Salvetti, H.G. de Carvalho, and J.B. Martins, Nuovo Cimento Lettere 1, 835 (1971).

18 V. di Napoli, D. Margadonna, F. Salvetti, H.G. de Carvalho, and J.B. Martins, Nucl. Inst. Meth. 93, 77 (1971).

20 V. di Napoli, F. Dobici, O. Forina, F. Salvetti and H.G. de Carvalho, Lett. Nuovo Cimento 55B, 95 (1968).

21 V. di Napoli, Nucl. Inst. Meth. 69, 155 (1969).

22 V.I. Noga, Yu.N. Ranyuk, P.V. Sorokin, and V.A. Tkachenko, Ukr. J. Phys. 16, 1850 (1971) in Russian.

ELEM. SYM.	A	Z
Na	23	11
REF. NO.		
74 Ve 1		egf

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
* G,N	ABX	12- 30	D	12- 30	BF3-I		4PI
** G,2N	ABX	23- 30	D	23- 30	BF3-I		4PI

\* 885+

\*\* 884

883+

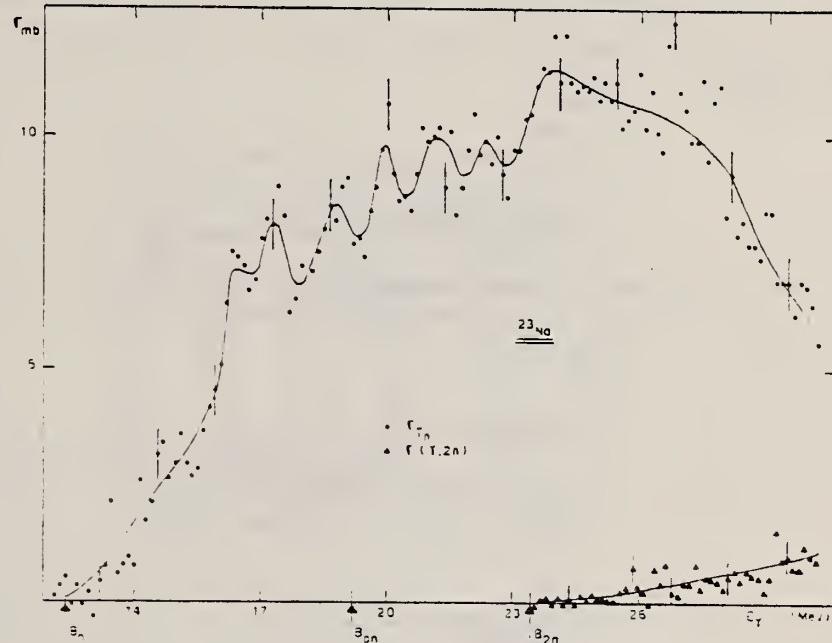


Fig. 5. Photoneutron cross sections  $\sigma_{Tn}$  and  $\sigma(\gamma, 2n)$  of  $^{23}\text{Na}$ .

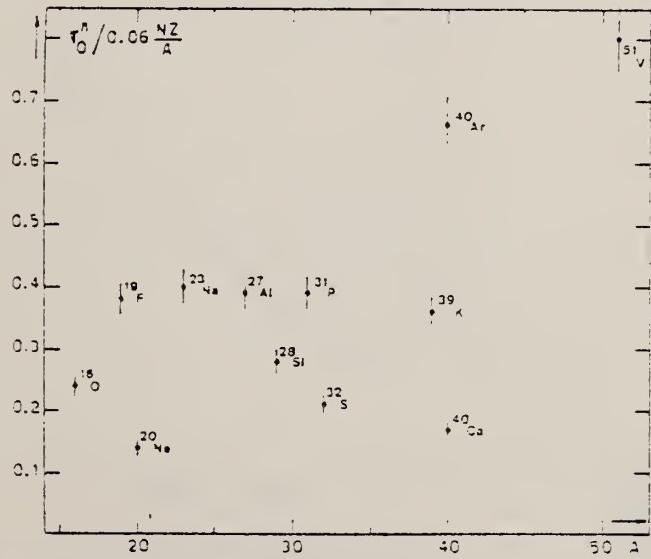


Fig. 22. Ratio of experimental integrated photoneutron cross section  $\sigma_0^n$  over the Thomas, Reiche and Kuhn sum rule [ $0.06 NZ/A$ ]. Numerical values and upper integration limits  $E_4$  are taken from table 3. Also  $\int \sigma_0^n = \pm 7\%$  for all nuclei.

(over)

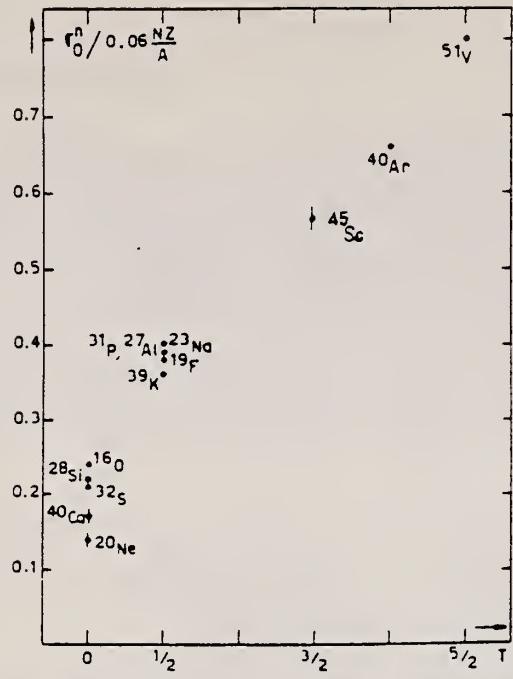


Fig. 24. The  $[\sigma_0^n / (0.06 NZ/A)]$  ratio as a function of isospin  $T$ . Possible overall errors of  $\pm 7\%$  are to be applied to all nuclei shown.

TABLE 3  
Experimental integrated photoneutron cross sections  $\sigma_0^n = \int_0^{E_M} \sigma_{TA}(E) dE$  compared with the classical sum rule  $[0.06 NZ/A]$  of Thomas, Reich and Kuhn

Nucleus	$T = 0$					$T = \frac{1}{2}$					$T = \frac{1}{2}; T = 2$			$T = \frac{3}{2}$
	$^{16}\text{O}$	$^{20}\text{Ne}$	$^{28}\text{Si}$	$^{32}\text{S}$	$^{40}\text{Ca}$	$^{19}\text{F}$	$^{23}\text{Na}$	$^{27}\text{Al}$	$^{31}\text{P}$	$^{39}\text{K}$	$^{45}\text{Sc}$	$^{40}\text{Ar}$	$^{51}\text{V}$	
$\sigma_0^n$ (MeV · mb)	58 $\pm 4$	42 $\pm 3$	94 $\pm 7$	98 $\pm 7$	100 $\pm 7$	108 $\pm 7$	137 $\pm 9$	158 $\pm 10$	182 $\pm 12$	210 $\pm 14$	383 $\pm 25$	393 $\pm 28$	602 $\pm 42$	
$\sigma_0^n / (0.06 NZ/A)$	0.24	0.14	0.22	0.21	0.17	0.38	0.40	0.39	0.39	0.36	0.57	0.66	0.8	
$E_M$ (MeV)	30	26.7	30	30	29.5	29	30	30	29	30	28.1	26.7	28	

REF.

V. di Napoli, G. Rosa, F. Salvetti, M. L. Terranova,  
 H. G. de Carvalho, J. B. Martins, O. A. P. Tavares  
 J. Inorg. Nucl. Chem. 37, 1101 (75)

ELEM. SYM.	A	Z
Na	23	11

METHOD

REF. NO.

75 Di 4

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,Fl8	ABY	21-999	C	300-999	ACT-I		4PI
G,NA22	ABY	12-999	C	300-999	ACT-I		4PI

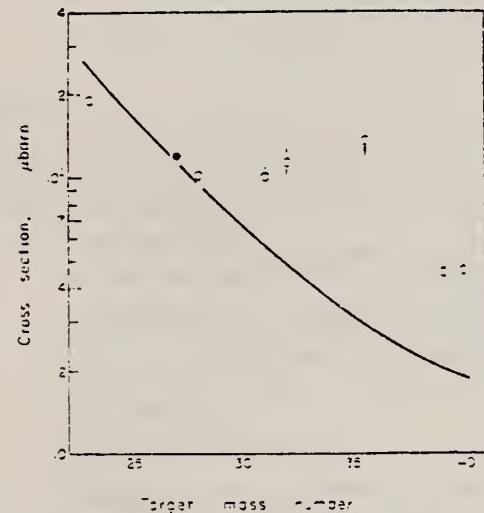


Fig. 2. Mean absolute cross section of  $^{18}\text{F}$  photoproduction vs the target mass number. Open triangle: energy range 0.15-0.72 GeV, Ref. [18]. Filled circle: energy range 0.3-1 GeV, Ref. [3]. Open circles: present work. The curve has been calculated by means of Eqn (1).

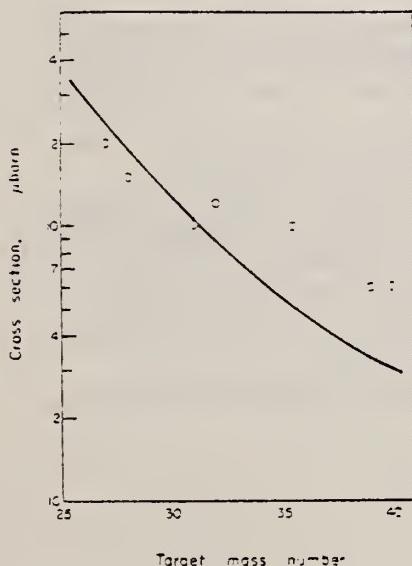


Fig. 3. Mean absolute cross section of  $^{22}\text{Na}$  photoproduction vs the target mass number. The curve has been calculated by means of Eqn (1).

Table 2. Cross-section per equivalent quantum  $\sigma_0(\mu\text{b})$  of photoproduction of  $^{18}\text{F}$

Target nucleus	Bremsstrahlung maximum energy $E_0(\text{GeV})$				
	0.30	0.40	0.55	0.75	1.00
$^{23}\text{Na}$	590 ± 30	640 ± 30	720 ± 30	780 ± 30	830 ± 30
$^{27}\text{Al}^*$	116 ± 7	172 ± 6	202 ± 6	245 ± 5	270 ± 5
$^{28}\text{Si}$	80 ± 10	110 ± 10	145 ± 10	170 ± 10	200 ± 10
$^{31}\text{P}$	60 ± 10	90 ± 10	130 ± 10	150 ± 10	180 ± 10
$^{32}\text{S}$	55 ± 10	90 ± 10	125 ± 10	160 ± 10	190 ± 10
$^{33}\text{Cl}$	185 ± 20	230 ± 20	270 ± 20	310 ± 20	350 ± 20
$^{36}\text{K}$	35 ± 5	50 ± 5	65 ± 5	75 ± 5	90 ± 5
$^{40}\text{Ca}$	5 ± 2	20 ± 3	35 ± 5	45 ± 5	60 ± 5

\*The results for  $^{27}\text{Al}$  have already been published (see [3]) and are reported for comparison.

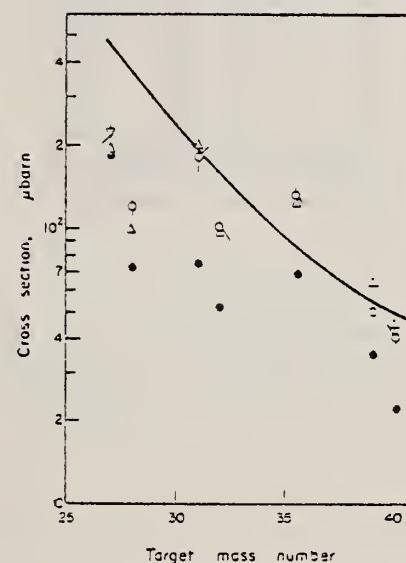


Fig. 4. Mean absolute cross section of  $^{23}\text{Na}$  photoproduction vs the target mass number. Filled circles: energy range 0.1-1 GeV, Ref. [20]. Reversed open triangle: energy range 0.3-1 GeV, Ref. [8]. Open triangles: energy range 0.25-1 GeV, Ref. [19]. Open circles: present work. The curve has been calculated by means of Eqn (1).

Table 3. Cross-section per equivalent quantum  $\sigma_0(\mu\text{b})$  of photoproduction of  $^{23}\text{Na}$

Target nucleus	Bremsstrahlung maximum energy $E_\gamma(\text{GeV})$				
	0.30	0.40	0.55	0.75	1.00
$^{27}\text{Al}^*$	490 $\pm$ 20	560 $\pm$ 20	667 $\pm$ 20	690 $\pm$ 20	745 $\pm$ 20
$^{28}\text{Si}$	290 $\pm$ 20	330 $\pm$ 20	330 $\pm$ 20	430 $\pm$ 20	470 $\pm$ 20
$^{31}\text{P}$	230 $\pm$ 20	250 $\pm$ 20	290 $\pm$ 20	330 $\pm$ 20	350 $\pm$ 20
$^{32}\text{S}$	206 $\pm$ 10	240 $\pm$ 10	280 $\pm$ 10	320 $\pm$ 10	350 $\pm$ 10
$^{35}\text{Cl}^*$	230 $\pm$ 10	260 $\pm$ 10	290 $\pm$ 10	320 $\pm$ 10	350 $\pm$ 10
$^{39}\text{K}$	30 $\pm$ 3	50 $\pm$ 5	65 $\pm$ 5	80 $\pm$ 5	100 $\pm$ 5
$^{40}\text{Ca}$	5 $\pm$ 2	20 $\pm$ 3	45 $\pm$ 5	60 $\pm$ 5	60 $\pm$ 5

Table 4. Cross-section per equivalent quantum  $\sigma_0(\mu\text{b})$  of photoproduction of  $^{23}\text{Na}$

Target nucleus	Bremsstrahlung maximum energy $E_\gamma(\text{GeV})$				
	0.30	0.40	0.55	0.75	1.00
$^{27}\text{Al}^*$	370 $\pm$ 10	440 $\pm$ 10	520 $\pm$ 20	550 $\pm$ 20	660 $\pm$ 20
$^{28}\text{Si}$	100 $\pm$ 10	140 $\pm$ 10	160 $\pm$ 10	210 $\pm$ 10	240 $\pm$ 10
$^{31}\text{P}$	100 $\pm$ 20	160 $\pm$ 20	200 $\pm$ 20	270 $\pm$ 20	310 $\pm$ 20
$^{32}\text{S}$	120 $\pm$ 10	160 $\pm$ 10	150 $\pm$ 10	210 $\pm$ 10	240 $\pm$ 10
$^{35}\text{Cl}^*$	65 $\pm$ 10	100 $\pm$ 10	140 $\pm$ 10	190 $\pm$ 10	220 $\pm$ 10
$^{39}\text{K}$	20 $\pm$ 5	35 $\pm$ 5	55 $\pm$ 5	65 $\pm$ 5	80 $\pm$ 5
$^{40}\text{Ca}$	12 $\pm$ 3	25 $\pm$ 5	35 $\pm$ 5	50 $\pm$ 5	60 $\pm$ 5

\*The results for  $^{27}\text{Al}$  have already been published (see [3]) and are reported for comparison.

Table 5. Mean absolute cross-section  $\bar{\sigma}_0(\mu\text{b})$  in the energy range 0.3-1 GeV

Target nucleus	Produced radionuclide		
	$^{18}\text{F}$	$^{23}\text{Na}$	$^{23}\text{Na}$
$^{23}\text{Na}$	190 $\pm$ 30		
$^{27}\text{Al}^*$	120 $\pm$ 10	200 $\pm$ 20	220 $\pm$ 20
$^{28}\text{Si}$	100 $\pm$ 10	150 $\pm$ 20	120 $\pm$ 10
$^{31}\text{P}$	100 $\pm$ 10	160 $\pm$ 20	180 $\pm$ 20
$^{32}\text{S}$	110 $\pm$ 10	120 $\pm$ 10	100 $\pm$ 10
$^{35}\text{Cl}^*$	135 $\pm$ 20	190 $\pm$ 10	130 $\pm$ 10
$^{39}\text{K}$	45 $\pm$ 5	60 $\pm$ 5	50 $\pm$ 5
$^{40}\text{Ca}$	46 $\pm$ 5	60 $\pm$ 5	40 $\pm$ 5

\*The results for the photoproduction of  $^{18}\text{F}$  and  $^{23}\text{Na}$  from  $^{27}\text{Al}$  have already been published (Ref.[3] and [8], respectively).

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ELEM. SYM.	A	z
Na	23	11

METHOD	REF. NO.	hg				
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE	RANGE	TYPE	RANGE
G,N	ABY	12-68	C	30-68	ACT-I	4PI

Analysis is made of reactions interfering with photon activation analysis procedures.

The activation yield curves have been presented for a number of photonuclear reactions in the energy range from 30 to 68 MeV, in order to evaluate quantitatively the interferences due to competing reactions in multielement photon activation analysis. The general features of the yields as functions of both target mass number and excitation energy were elucidated from the data obtained, discussion being given on the results in terms of the reaction mechanism.

Simultaneous neutron activation due to appreciable neutron production from the converter and surrounding materials has also been studied, and, finally, the magnitudes of interferences in real multielement analysis were given in the form of their energy dependences.

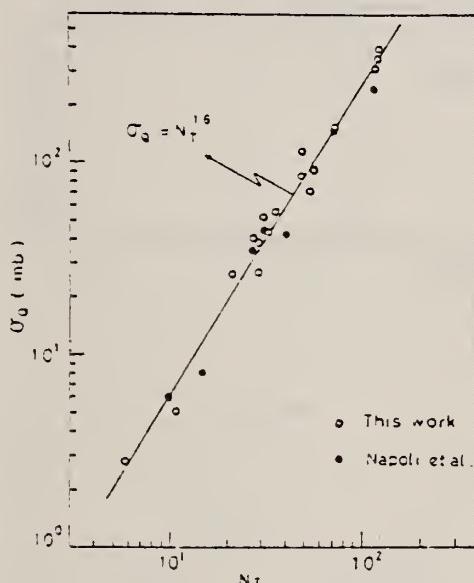


Fig. 2. Yield per equivalent quanta versus target neutron number.

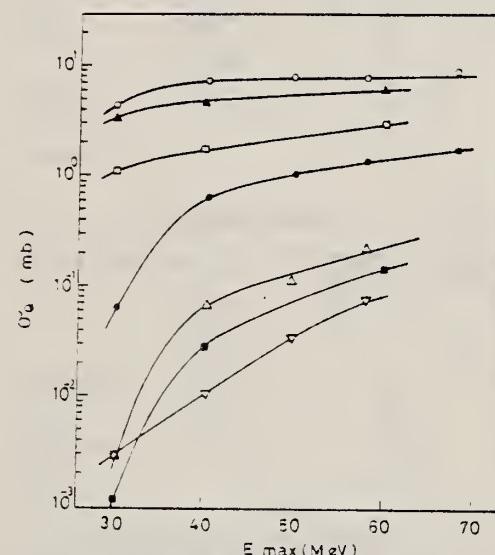


Fig. 3. Activation yield curves for the reactions on C, Na, Mg and Al

$\square$   $^{12}\text{C}(\gamma, n)^{11}\text{C}$ ,  $\blacksquare$   $^{12}\text{C}(\gamma, xn)^7\text{Be}$ ,  $\blacktriangle$   $^{23}\text{Na}(\gamma, n)^{22}\text{Na}$ ,  
 $\circ$   $^{25}\text{Mg}(\gamma, p)^{24}\text{Na}$ ,  $\bullet$   $^{24}\text{Mg}(\gamma, xn)^{22}\text{Na}$ ,  $\triangle$   $^{27}\text{Al}(\gamma, xn)^{24}\text{Na}$ ,  
 $\square$   $^{27}\text{Al}(\gamma, n)^{27}\text{Al}$

(over)

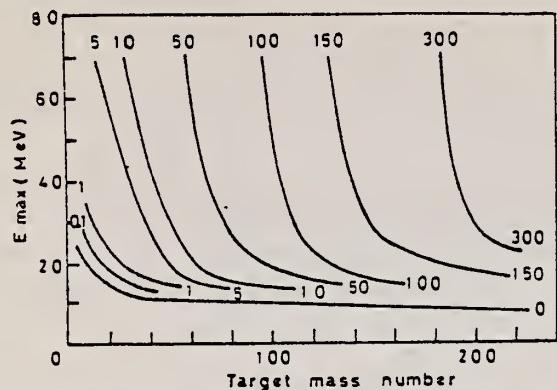


Fig. 9. Yields of the  $(\gamma, n)$  reactions as a function of bremsstrahlung maximum energy and target mass number. The numerical values in the figure are yields per equivalent quanta in mb.

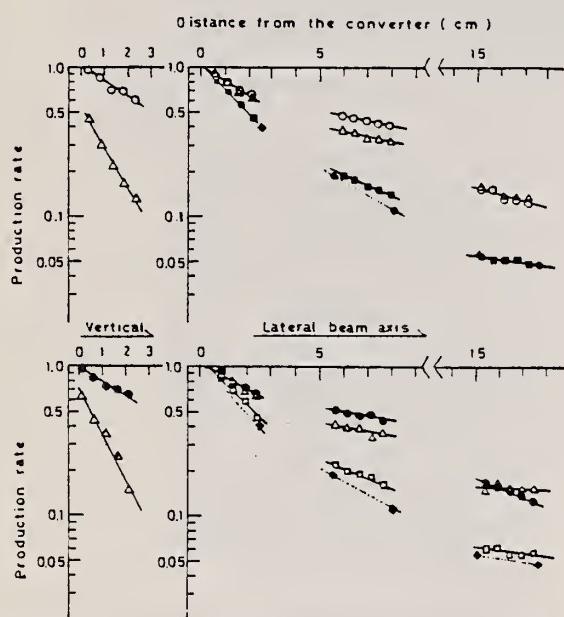


Fig. 13. Production rates of the neutron reactions and the photonuclear reactions as a function of distance from the converter in vertical and lateral directions.  
 ○  $^{55}\text{Mn}(n, \gamma)^{56}\text{Mn}$ , ●  $^{23}\text{Na}(n, \gamma)^{24}\text{Na}$ , △  $^{27}\text{Al}(n, x)^{24}\text{Na}$ ,  
 ■  $^{55}\text{Mn}(\gamma, n)^{54}\text{Mn}$ , □  $^{23}\text{Na}(\gamma, n)^{22}\text{Na}$ , ◆  $^{63}\text{Cu}(\gamma, n)^{64}\text{Cu}$ .

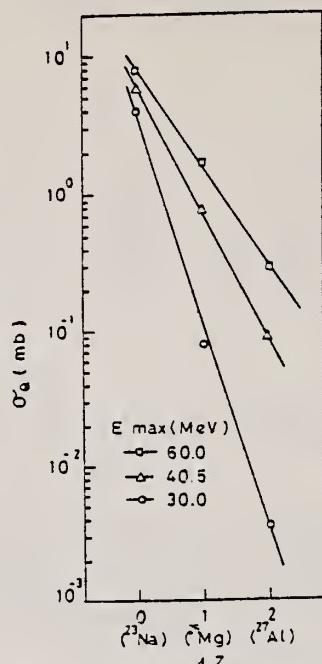


Fig. 12. The reaction yields leading to  $^{22}\text{Na}$  as a function of difference in atomic number between target and product nuclides

REF. B.S. Ishkhanov, V.I. Mokeev, Yu.A. Novikov, E.S. Omarov,  
 I.M. Piskarev, A.M. Parlag, A.I. Gutii  
 Sov. J. Nucl. Phys. 32, 455 (1980)  
 Yad. Fiz. 32, 885 (1980)

ELEM. SYM.	A	Z
Na	23	11

METHOD

REF. NO.

80 Is 2

\*

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,PG/	ABI	8-32	C	13-32	SCD-D		135
G,NG/	ABI	12-32	C	13-32	SCD-D		135

Energy spectra of photons from the reaction  $^{23}\text{Na}(\gamma, X\gamma')$  have been measured. Integrated cross sections have been determined for population of the individual levels of the nuclei  $^{23}\text{Na}$  and  $^{22}\text{Ne}$ . The energy dependence of the cross section for excitation of the 1.27-MeV level of the  $^{22}\text{Ne}$  nucleus in the  $(\gamma, \rho\gamma')$  reaction is obtained. The results are compared with spectroscopic data existing in the literature.

(G,PG/)

(G,NG/)

ABI FOR 5 LEVELS

ABI FOR 3 LEVELS

PACS numbers: 25.20. + y, 27.30. + t

TABLE I. Levels populated in the reaction  $^{23}\text{Na}(\gamma, X\gamma')$  at  $E_{\max} = 32$  MeV.

$E_X$ , MeV (Ref. 2)	Final nucleus	$J^\pi, T$ (1)	Integrated cross section, MeV · mb (present work)	Spectroscopic factors $C^2 S$	
				$l^M$	$M$
1.27 ± 0.01		$2^+$	15 ± 4	1.2	
3.36 ± 0.03		$4^+$	5 ± 2	0.41	
4.46	$^{22}\text{Ne}$	$2^+$	$\leq 2$	0.15-0.3	
5.15		$2^-$	$\leq 20$	1.7	
5.23; 5.36;					
5.52; 5.64;					
5.92			$\leq 1$	-	
1.99 ± 0.02		$2^+, 1^-$	5 ± 2		1.2
5.60 ± 0.04	$^{23}\text{Na}$	$(1, 2)^-$	$2 \pm 1$		0.08
5.73 ± 0.04			$2 \pm 1$		-

\*Obtained on the assumption that the level width is 200 keV.

TABLE II. Values of errors in determination of the integrated cross section for population of levels

Photon energy, MeV	Error, MeV · mb
0.55	10
1.0	5
1.5	3
2-4	2
5-6	1

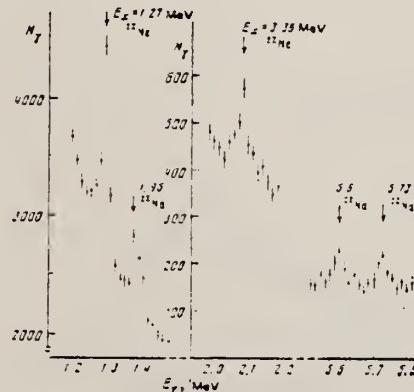


FIG. 1. Portions of the energy spectrum of  $\gamma$  rays from the reaction  $^{23}\text{Na}(\gamma, X\gamma')$  for a bremsstrahlung maximum energy 32 MeV. The numbers by the arrows are values of  $E_X$ .

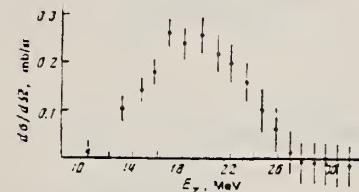


FIG. 2. Differential cross section for the reaction  $^{23}\text{Na}(\gamma, \rho\gamma')$ , leading to population of the 1.27-MeV level of the  $^{22}\text{Ne}$  nucleus.

ELEM. SYM.	A	Z
Na	23	11
REF. NO.		
80 Ya 2		hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, F18	YLD	THR-60	C	30-60	ACT-I		4PI

The production rates of  $^{18}\text{F}$  by the  $^{20}\text{Ne}(\gamma, pn)^{18}\text{F}$  plus  $^{20}\text{Ne}(\gamma, 2n)^{18}\text{Ne} \rightarrow ^{18}\text{F}$ ,  $^{23}\text{Na}(\gamma, 2n)^{18}\text{F}$ , and  $^{19}\text{F}(\gamma, n)^{18}\text{F}$  reactions were determined as a function of the maximum bremsstrahlung energies between 30 and 60 MeV. In addition, a simple and fast method to prepare anhydrous  $\text{H}^{18}\text{F}$  was studied by using  $\text{KHF}_2$  target.

TABLE I. Photonuclear reactions for  $^{18}\text{F}$  production

Target nuclide (abundance, %)	Reaction type	Threshold energy (MeV)	Product nuclide
$^{20}\text{Ne}$ (90.51)	$(\gamma, 2n)$	23.50	$^{18}\text{Ne} \rightarrow ^{19}\text{F}$
$^{21}\text{Ne}$ (0.27)	$(\gamma, 3n)$	35.27	$^{18}\text{Ne} \rightarrow ^{18}\text{F}$
$^{22}\text{Ne}$ (9.22)	$(\gamma, 4n)$	45.63	$^{18}\text{Ne} \rightarrow ^{19}\text{F}$
$^{20}\text{Ne}$ (90.51)	$(\gamma, pn)$	23.26	$^{18}\text{F}$
$^{21}\text{Ne}$ (0.27)	$(\gamma, p2n)$	29.93	$^{18}\text{F}$
$^{22}\text{Ne}$ (9.22)	$(\gamma, p3n)$	40.38	$^{18}\text{F}$
$^{23}\text{Na}$ (100)	$(\gamma, 2n)$	20.89	$^{18}\text{F}$
$^{19}\text{F}$ (100)	$(\gamma, n)$	10.43	$^{18}\text{F}$

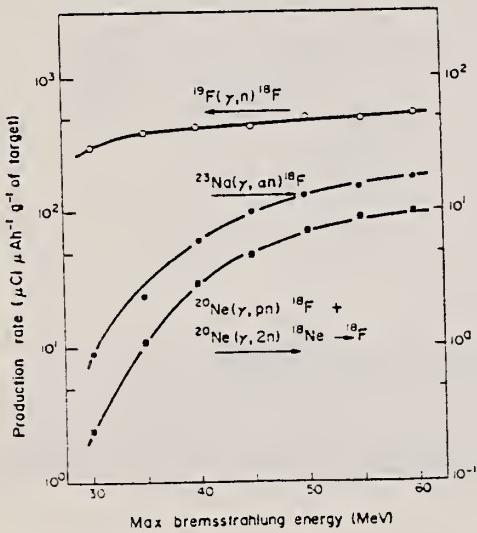


FIG. 1. Production rates of  $^{18}\text{F}$  on Ne, Na and F targets as a function of the maximum bremsstrahlung energy.

REF. B.S. Ishkhanov, I.M. Kapitonov, V.I. Shvedunov, A.I. Gutii,  
 A.M. Parlag  
 Sov. J. Nucl. Phys. 33, 303 (1981)  
 Yad. Fiz. 33, 581 (1981)

ELEM. SYM.	A	Z
Na	23	11
REF. NO.	81 Is 3	hg

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR	
			TYPE	RANGE	TYPE	RANGE
G, P	ABX	8-30	C	16-30	TEL-D	90

Total  $\sigma(\gamma, p)$  obtained by summing the various photoproton cross sections and multiplying by  $4\pi$ .

$$\int_{Th}^{29.5} \sigma(\gamma, p) dE = 190 \pm 20 \text{ MEV} \cdot \text{mb}$$

The photoproton spectra from  $^{23}\text{Na}$  have been measured in a bremsstrahlung beam. The bremsstrahlung maximum energy was varied over the range 16–30 MeV in 1-MeV steps. The photoproton spectra were analyzed to obtain cross sections for the reaction  $^{23}\text{Na}(\gamma, p)^{22}\text{Ne}$  with formation of the final nucleus in various states. The experimental results are interpreted on the basis of spectroscopic information on the low-lying levels of  $^{22}\text{Ne}$  obtained in the reaction  $^{23}\text{Na}(d, ^3\text{He})^{22}\text{Ne}$ . An estimate is given of the contribution of  $1p-1h$  configurations to formation of the proton channel of decay of the giant dipole resonance of  $^{23}\text{Na}$ . The centers of gravity of the electric dipole transitions from various shells are determined.

PACS numbers: 25.20. + y, 27.30. + t, 23.20.Lv

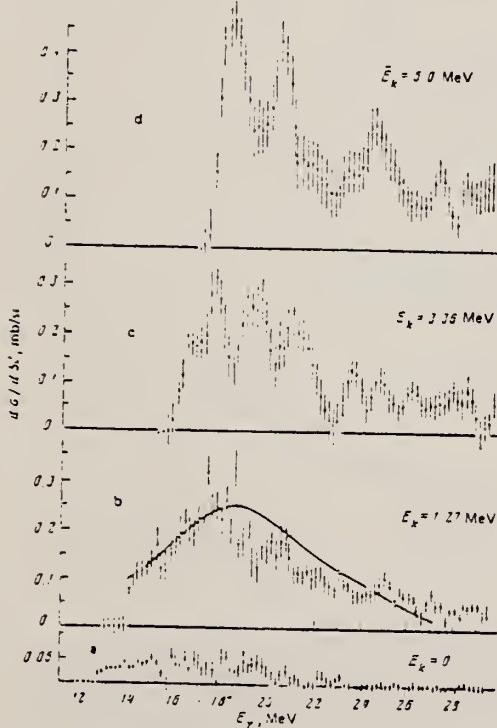


FIG. 4. Cross section for the reaction  $^{23}\text{Na}(\gamma, p)^{22}\text{Ne}$  with formation of the final nucleus in the ground state (a), first excited state (b), second excited state (c), and also in the group of states at energy 5.0 MeV (d). The solid line in Fig. 4b shows the cross section obtained in Ref. 11.

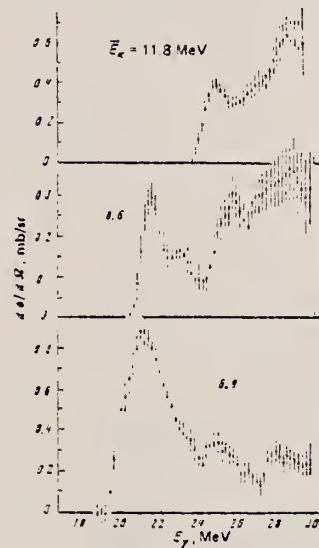


FIG. 5. Cross sections for the reaction  $^{23}\text{Na}(\gamma, p)^{22}\text{Ne}$  with formation of the final nucleus in groups of states at energies 6.9, 8.9 and 11.8 MeV.

(OVER)

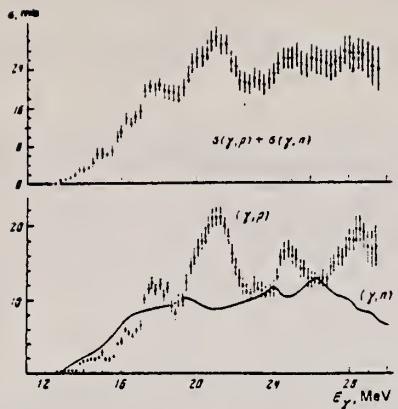


FIG. 6. Total cross section for the reaction  $^{23}\text{Na}(\gamma, p)^{22}\text{Ne}$  (lower figure) and cross section for absorption of photons by  $^{23}\text{Na}$  (upper figure) obtained by summation of the photoproton and photoneutron cross sections.<sup>1-3</sup> The latter is shown by the solid line in the lower figure.

ELEM. SYM.	A	Z
Na	23	11

REF. NO.  
81 Is 8  
egf

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, P0	ABX	12-29	C	16-30	TEL-D		90
G, P1	ABX	14-29	C	16-30	TEL-D		90
G, P2	ABX	16-29	C	16-30	TEL-D		90
G, PN	ABX	19-29	C	16-30	TEL-D		90

The photoproton spectra from  $^{23}\text{Na}$  have been measured in a bremsstrahlung beam. The bremsstrahlung maximum energy was varied over the range 16-30 MeV in 1-MeV steps. The photoproton spectra were analyzed to obtain cross sections for the reaction  $^{23}\text{Na}(\gamma, p)^{22}\text{Ne}$  with formation of the final nucleus in various states. The experimental results are interpreted on the basis of spectroscopic information on the low-lying levels of  $^{22}\text{Ne}$  obtained in the reaction  $^{23}\text{Na}(d, p)^{22}\text{Ne}$ . An estimate is given of the contribution of  $1p-1h$  configurations to formation of the proton channel of decay of the giant dipole resonance of  $^{23}\text{Na}$ . The centers of gravity of the electric dipole transitions from various shells are determined.

PACS numbers: 25.20. + y, 27.30. + t, 23.20.Lv

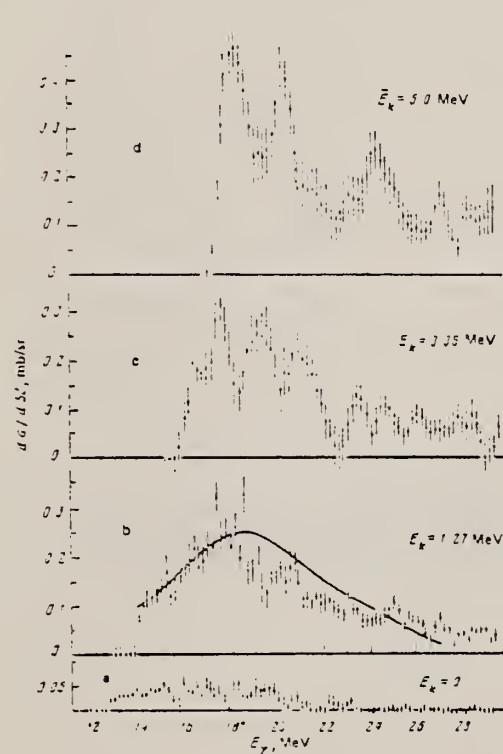


FIG. 4. Cross section for the reaction  $^{23}\text{Na}(\gamma, p)^{22}\text{Ne}$  with formation of the final nucleus in the ground state (a), first excited state (b), second excited state (c), and also in the group of states at energy 5.0 MeV (d). The solid line in Fig. 4b shows the cross section obtained in Ref. 11.

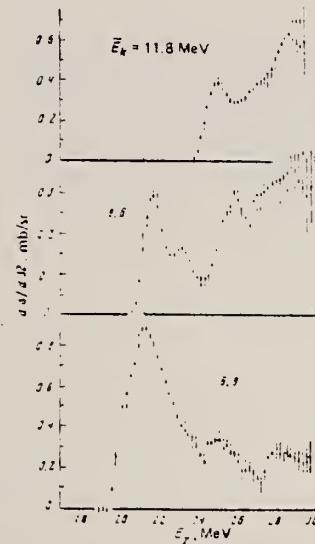


FIG. 5. Cross sections for the reaction  $^{23}\text{Na}(\gamma, p)^{22}\text{Ne}$  with formation of the final nucleus in groups of states at energies 6.9, 8.9 and 11.8 MeV.

TABLE I. Energy resolution of partial cross sections and probability of formation of the  $^{22}\text{Ne}$  nucleus in various states.

Number of partial cross sections $k$	Energy $E_k$ of a final state or the center of gravity $\bar{E}_k$ of the group of states, MeV		Energy resolution, MeV	Probability
	E	$\bar{E}_k$		
1	0		0.4	0.02
2	1.37		0.3	0.12
3	3.26		1.0	0.11
4	5.16	5.14	1.2	0.15
5		8.9	1.3	0.27
6		8.9	1.5	0.14
7		11.8	2.0	0.16

(OVER)

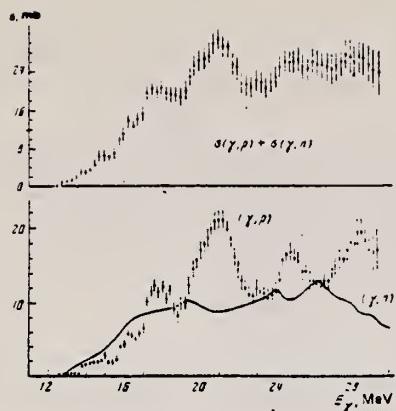


FIG. 6. Total cross section for the reaction  $^{23}\text{Na}(\gamma, p)^{22}\text{Ne}$  (lower figure) and cross section for absorption of photons by  $^{23}\text{Na}$  (upper figure) obtained by summation of the photoproton and photoneutron cross sections.<sup>7,8</sup> The latter is shown by the solid line in the lower figure.

REF. B.S. Ishkhanov, Yu.A. Novikov, E.S. Omarov, I.M. Piskarev,  
 V.M. Sorvin, A.I. Gutii, A.M. Parlag  
*Yad. Fiz.* 35, 3 (1982)  
*Sov. J. Nucl. Phys.* 35, 1 (1982)

ELEM. SYM.	A	z
Na	23	11
REF. NO.		
82 Is 2		egf

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR	
			TYPE	RANGE	TYPE	RANGE
G,G	ABX	7-31	C	7-31	NAI-D	90

The cross section for elastic scattering of photons by the  $^{23}\text{Na}$  nucleus has been measured in the energy ranges 7-14 and 16-31 MeV. At energies 16-31 MeV the cross sections for the nuclear Raman effect and for inelastic scattering of photons with population of the 2.03-MeV level are obtained. The results are discussed in the framework of the shell model. The contributions of various shell configurations to the formation of the giant resonance in  $^{23}\text{Na}$  are evaluated.

PACS numbers: 25.20. + y, 27.30. + t

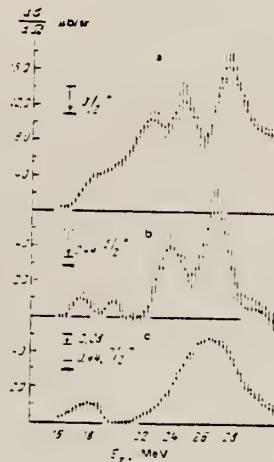


FIG. 2. Differential cross sections for photon-scattering channels in the region of the giant resonance: a—elastic scattering, b—nuclear Raman effect, c—inelastic scattering with excitation of the 2.03-MeV level.

TABLE II. Position of maxima in the cross sections for the various photon-scattering channels.

Elastic scattering, $J^\pi = 3/2^+$	NRE, 0.44 MeV, $J^\pi = 5/2^+$	Inelastic scattering with excitation of the 2.03-MeV level, $J^\pi = 7/2^+$	Elastic scattering, $J^\pi = 3/2^+$	NRE, 0.44 MeV, $J^\pi = 5/2^+$	Inelastic scattering with excitation of the 2.03-MeV level, $J^\pi = 7/2^+$
18.0±0.5	17.7±0.5	18.0±0.5	21.6±0.5	—	—
12.5±0.5	10.3±0.3	—	—	27.1±0.5	26.5±0.5



## MAGNESIUM

Z=12

Because the metal is so reactive, man's first knowledge of magnesium came from its compounds. In 1618, Henry Wicker (or Wickes) noticed a small hole filled with water on the common at Epsom, Surrey. Even though there was a draught, not one of his thirsty cattle would drink the water. The water, althought bitter, was found to be useful as an internal medicine and as a bath to heal external wounds. Within 30 years, Epsom became a famous spa and attracted visitors from all over the continent. The English botanist Nehemiah Grew (1641-1712) in 1695 isolated the salts (magnesium sulphate) from this well and recognized it as a unique substance.

MG

Sir Humphry Davy in 1808 produced a small amount of the metal by electrolyzing magnesium sulphate using metallic mercury as the cathode. This process yielded magnesium, not in a pure form, but as an amalgam. It was two years later in 1828 that the metal was first actually isolated. A. Bussy (1794-1882) obtained it by fusing magnesium chloride with metallic potassium. He called it magnium because as he said, the word magnesium is easily confused with manganese. Nevertheless, the word magnesium persisted.

MG



## METHOD

Linac; counted delayed neutrons from N<sup>17</sup>

**REF. NO.**

55 Re 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N17	ABI	THR - 400	C	80-400	ACT-I	/	4PI

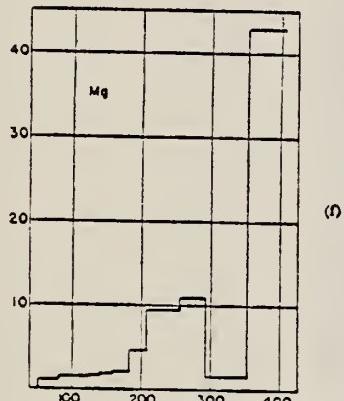
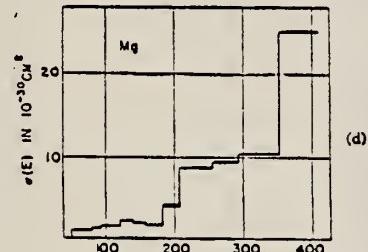
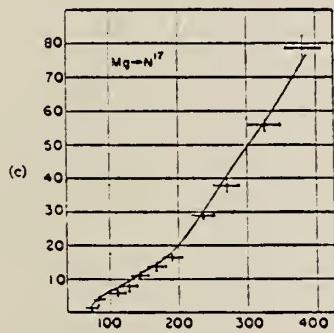
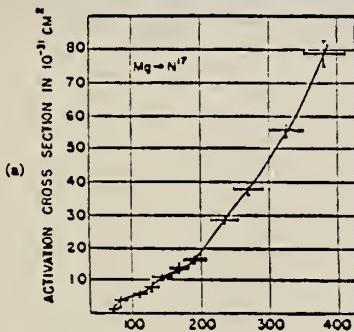


Fig. 5. Graphs a, b, and c show activation points for  $N^{71}$  yields in magnesium and aluminum. Graphs d, e, and f are the calculated photon cross sections, from which the solid lines in a, b, and c have been reconstructed. The thin cross-section curve is actually the slightly modified result of an early aluminum run, and is included to illustrate the effects of moderate errors in data upon the photo-cross section results.

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
Mg ( $\gamma, \gamma$ )	Bremss. 4-40					<p>Detector at <math>120^\circ</math>.</p> <p>Cross sections given here are 13% too high due to erroneous <math>\cos \theta</math> factor in denominator of Eq. (5). [See footnote 8 in Phys. Rev. <u>106</u>, 993 (1957)].</p>

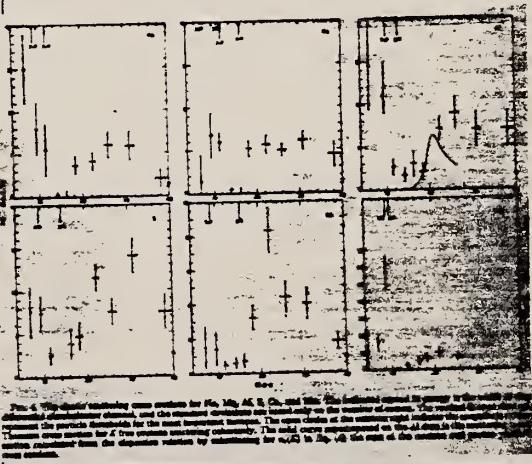


FIG. 4. Theoretical branching cross sections for Mg, Mg, Al, Si, Cr, and Mn. The theoretical calculations were made by the method of reference 1. The experimental data points are the same as those given in reference 1. The theoretical curves are for the most important terms. The open circles at the bottom right of each panel represent the total cross sections for  $\Delta^2$  free electrons scattering elastically. The solid curve represents the differential cross section calculated from the dispersion relation by summing for  $\omega/2$  to  $\omega/40$  the sum of the various contributions.

Elem. Sym.	A	Z
Mg		12

Method Neutron detector; Bremsstrahlung.

Ref. No.  
 56 Ye 1

EGF

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
( $\gamma$ , xn)	7-23					<p><math>Mg^{24}(\gamma, n)_{th} = 16.57</math> MeV</p> <p><math>Mg^{25}(\gamma, n)_{th} = 7.33</math> MeV</p> <p><math>Mg^{26}(\gamma, n)_{th} = 11.12</math> MeV</p> <p><u>Figure 1:</u> Yield of neutrons <u>versus</u> gamma-ray energy for natural magnesium samples. Points shown with estimated error ellipses are for the present work. Crosses are from reference 2 [Katz <i>et al.</i>, Canad. J. Phys. 32, 580 (1954)], scaled by a factor 0.74 to give agreement with the present work at 20 MeV. Triangles are the Mg<sup>25</sup> yield data for reference 5 [Phys. Rev 98, 1296 (1954)], adjusted for the isotopic abundance of Mg<sup>25</sup> in natural Mg. The (<math>\gamma, n</math>) thresholds for the 3 Mg isotopes are indicated along the abscissa. Over the energy range from threshold to about 16 MeV the yield values are plotted to a scale expanded 5 times over the scale given. From about 12.5 MeV to the upper energy limit of the data, the points are plotted to the scale shown. (The points from 12.5 to 16 MeV are plotted to both scales).</p>

Elem. Sym.	$\Delta$	Z
Mg		12

Method 18 MeV electron synchrotron;  $\text{BF}_3$  counters; 0.25 r Victoreen thimble ionization chamber; 8cm Lucite monitor.

Ref. No.  
 58 Sp 2 EH

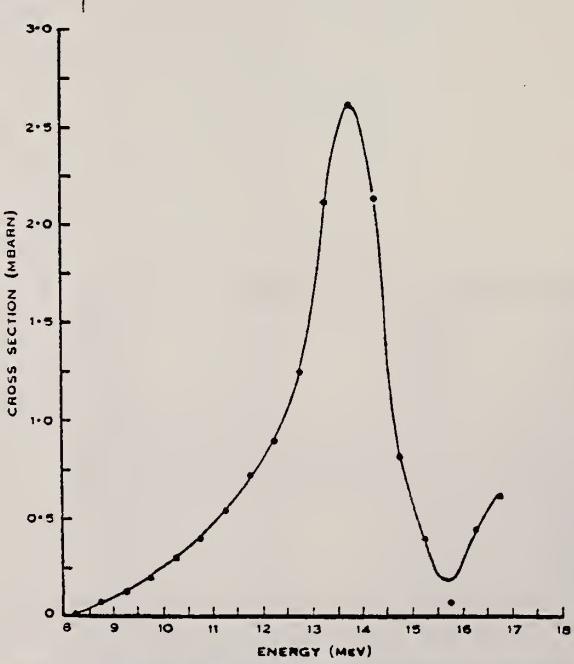
Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes																												
Mg ( $\gamma, n$ )	8-17	13.5				$\sigma_{\max} = 2.5 \text{ mb}$ At $E = 17 \text{ MeV}$ , absolute yield of neutrons calculated to be $4 \times 10^4 \text{ n m}^{-1} \text{ r}^{-1}$ .  <table border="1"> <caption>Data points estimated from Figure 2</caption> <thead> <tr> <th>Energy (MeV)</th> <th>Cross Section (mbarn)</th> </tr> </thead> <tbody> <tr><td>8.0</td><td>0.0</td></tr> <tr><td>9.0</td><td>0.1</td></tr> <tr><td>10.0</td><td>0.3</td></tr> <tr><td>11.0</td><td>0.5</td></tr> <tr><td>12.0</td><td>0.8</td></tr> <tr><td>13.0</td><td>1.2</td></tr> <tr><td>13.5</td><td>2.1</td></tr> <tr><td>14.0</td><td>2.5</td></tr> <tr><td>14.5</td><td>2.2</td></tr> <tr><td>15.0</td><td>0.8</td></tr> <tr><td>15.5</td><td>0.4</td></tr> <tr><td>16.0</td><td>0.5</td></tr> <tr><td>17.0</td><td>0.6</td></tr> </tbody> </table>	Energy (MeV)	Cross Section (mbarn)	8.0	0.0	9.0	0.1	10.0	0.3	11.0	0.5	12.0	0.8	13.0	1.2	13.5	2.1	14.0	2.5	14.5	2.2	15.0	0.8	15.5	0.4	16.0	0.5	17.0	0.6
Energy (MeV)	Cross Section (mbarn)																																	
8.0	0.0																																	
9.0	0.1																																	
10.0	0.3																																	
11.0	0.5																																	
12.0	0.8																																	
13.0	1.2																																	
13.5	2.1																																	
14.0	2.5																																	
14.5	2.2																																	
15.0	0.8																																	
15.5	0.4																																	
16.0	0.5																																	
17.0	0.6																																	

Fig. 2.—Cross section for photoneutron production from natural magnesium.

REF.

M. Langevin and A. Bussiere de Nercy  
 J. Phys. Radium 20, 831 (1959) (See 61 Bu 4)

ELEM. SYM.

Mg

12

METHOD

REF. NO.

59 La 1

EGF

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	10 (10.3±0.5)	C	13	NAI-D	0 - 12	135

$$\int \sigma_s dE = 2.24 \pm 0.44 \text{ MeV-mb}$$

$$\Gamma_\gamma = 22 \pm 4 \text{ eV}$$

METHOD

Synchrotron; proton-neutron cross section; radioactivity

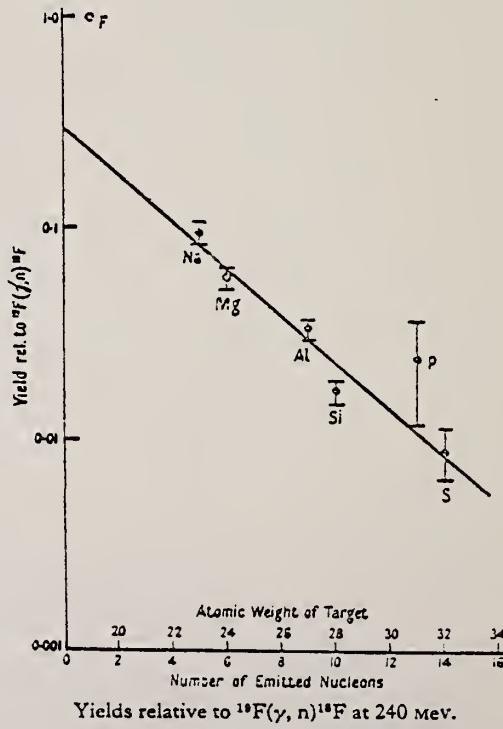
REF. NO.

60 Wa 2

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, 2N3P	ABX	THR-240	C	240	ACT-I		4PI

$$\sigma = (0.20 \pm 0.02) 10^{-27} \text{ cm}^2 / \text{equivalent quantum}$$

Yields relative to  $^{18}\text{F}(\gamma, n)^{18}\text{F}$  at 240 Mev.

METHOD

REF. NO.

61 Bu 4

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	ABX	15-30	C	27,32	NAI-D		140

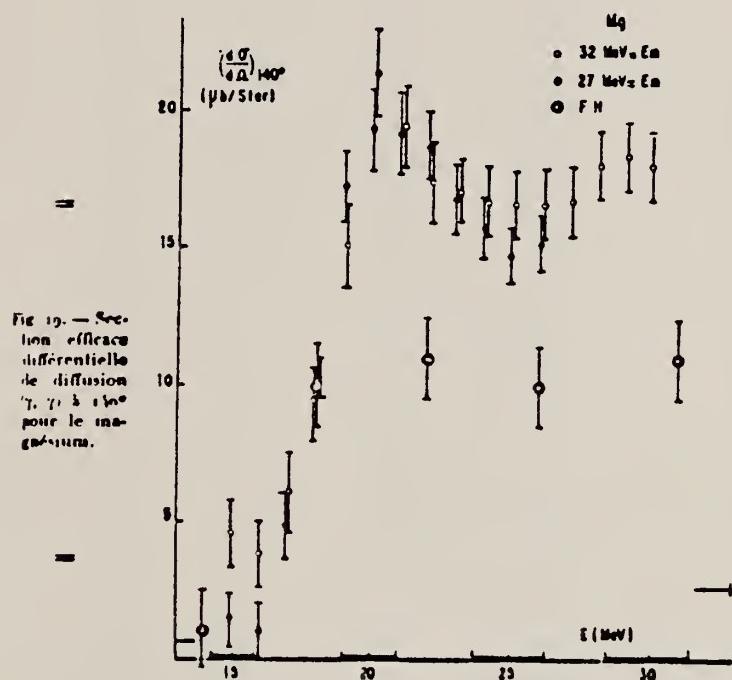


Fig. 19. — Section efficace différentielle de diffusion  $\langle\frac{d\sigma}{d\Omega}\rangle_{\text{MeV}}$  pour le magnésium.

Elem. Sym.	A	Z
Mg	12	

Method 25 MeV betatron; photon scattering; NaI(Tl) spectrometer;  
 ion chamber

Ref. No.  
 61 Su 1  
 25

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
Mg( $\gamma, \gamma$ )	Bremss. 7-14	10.2 9.3	+1.2 3.8 -0.6 eV 0.9 eV		$1^+$ $1^+$	Detector at 120°.



Fig. 2. The spectra of the scattered photons from the Mg scatterer. The solid line is the spectra measured without the Mg absorber and the broken line with the absorber. They are all normalized to the unit charge of the ionization chamber.

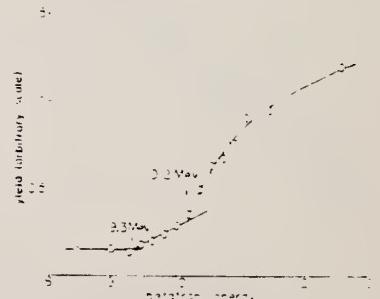


Fig. 4. The yield curve for Mg. The count at each bombarding energy of the incident bremsstrahlung was normalized to the unit charge from the monitor. The vertical lines show the statistical errors.

Elem. Sym.	A	Z
Mg		12

Method

Linac; NaI; detector at 90°.

Ref. No.

62 Se 1

JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
Mg ( $\gamma, \gamma$ )	Bremss; 16	10.6				<p>Other, unresolved lines in region ~ 9.2 MeV indicated.</p> <p>Spectrum in contradiction with conclusion of Langevin and de Nercy [J. Phys. Rad. 20, 831 (1959)]; that peak results from two <math>\gamma</math>-rays: one to ground state; the other to first excited state.</p>

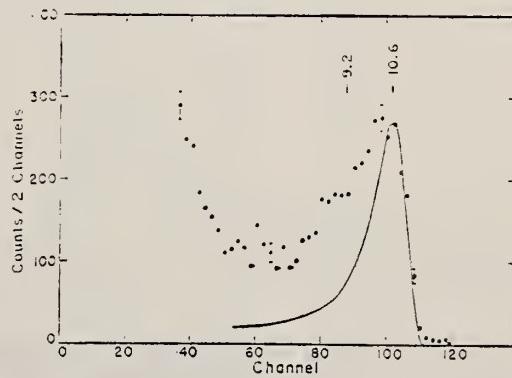
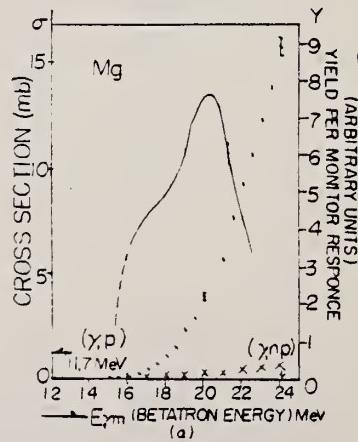


FIG. 7. Pulse-height spectrum for  $\gamma$  rays scattered from a Mg sample. Sample-out background has been subtracted. The solid line is a KS response function for a 10.6-Mev  $\gamma$  ray.

Method 25 MeV betatron; proton yield; scintillator; ion chamber.					Ref. No. 62 Sh 11	NVB
------------------------------------------------------------------	--	--	--	--	----------------------	-----

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
Mg( $\gamma$ , p)	Bremss. Thr-24	20	6 MeV	$\int_0^{23} = 0.070 \text{ MeV}\cdot\text{b}$		$\sigma_{\max} = 16 \text{ mb.}$  6 Detectors at angles: $20^\circ$ $55^\circ$ $90^\circ$ (2) $125^\circ$ $160^\circ$  Measured all protons above $E_0 = 1.5 \text{ MeV}$



Ref.

S. Costa, F. Ferraro, S. Verzani, D. Minocci, G. Malina  
 R. Malvezzi  
*Phys. Letters* 5, 296 (1963)

Elem. Sym.	A	Z
Mg		12

Method

100 MeV Synchrotron; 4  $\pi$  neutron detector; calculated integrated cross sections - fitted with polynomial of degree n

Ref. No.

63 Ce 3

327

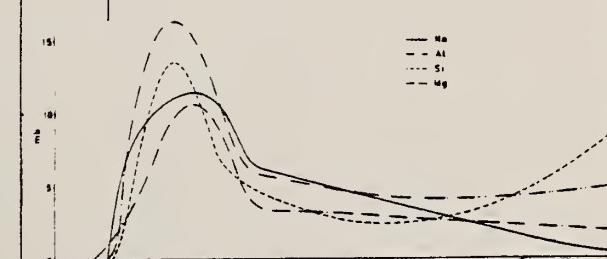
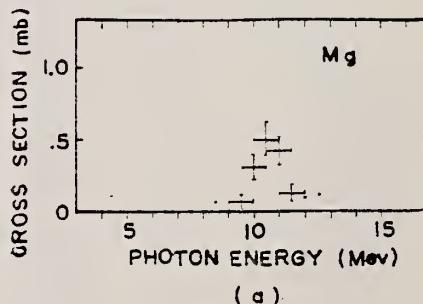
Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
( $\gamma$ , xn)						$\sigma_b = \frac{r^2 \Gamma(n)}{2} \frac{dE}{dx}$ <p>gets <math>\langle \hat{v}_p \cdot \hat{v}_n - \hat{v}_n \cdot \hat{v}_{n'} \rangle</math></p> $= (2e^2 - E_p^2 - \frac{3}{11} \frac{55}{62} e^2) b \frac{\Delta-1}{\Delta^2} \propto \frac{2}{\Delta-2}$ <p>See "Brown" for plots of this and <math>\frac{d\sigma}{dx}/60 \text{ MeV/A}</math>.</p> 

Figure 1: Photoneutron cross sections for several light elements versus  $\gamma$ -ray energy.

Method 25 MeV betatron; photon scattering; NaI spectrometer; NBS chamber

Ref. No.	
63 Su 1 C 5	NVB

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
Mg( $\gamma, \gamma$ )	Bremss. 4-14	10.2		$\int_4^{14} = 0.6 \text{ MeV-mb}$		<p>Detector at <math>120^\circ</math></p> <p><math>\sigma_{\max} = 0.5 \text{ mb}</math></p> <p>Corrects results of J. Phys. Soc. Japan <u>16</u>, 1657 (1961)</p>



REF.

B. S. Dolbilkin, V. A. Zapevalov, V. I. Korin, L. E. Lazareva and  
 F. A. Nikolaev  
 Proc. Paris Conference 1060 (1964)

ELEM. SYM.	A	Z
Mg		12

METHOD

REF. NO.

Synchrotron

64 Do 2

JDM

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
MU-T	G, MU-T	12-30	C	250	MGP-D	12-30	4PI

$$\int_{12}^{30} \sigma dE = 332 \pm 40 \text{ MeV.mb}$$

$\hbar\nu \dots (\text{MeV}) \dots \dots \dots$	13.9	17.0	18.9	20.3	23.1	24.8
$\sigma_{\text{max}} \text{ (mb)} \dots \dots \dots$	7	16	37	41	30	32
Half-width $\Gamma \text{ (MeV)} \dots \dots \dots$	$\sim 0.9$	$\sim 0.7$	$\sim 1.0$	$\sim 1.0$	$\sim 2.7$	$\sim 0.9$
$\int \sigma d(\hbar\nu) \text{ (MeV.mb)} \dots \dots \dots$	14	20	55	64	95	53

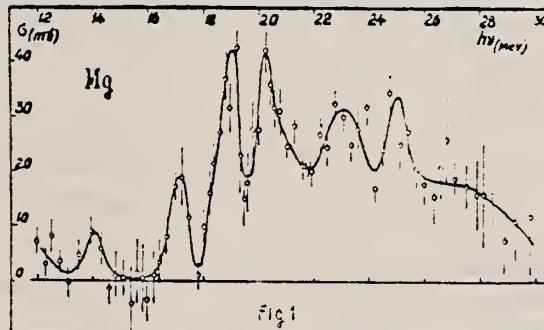


Fig. 1

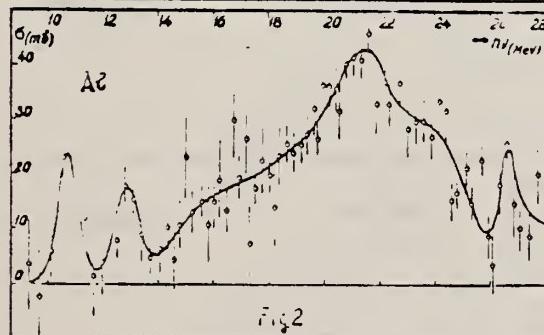


Fig. 2

FIG. 1. — Nuclear  $\gamma$ -ray absorption cross-section of Mg ( $Mg^{24}$  — 78.6,  $Mg^{26}$  — 10.1,  $Mg^{28}$  — 11.3 per cent).

The cross sections for Mg in the above figure have to be raised by 2.5 mb.

FIG. 2. — Nuclear  $\gamma$ -rays absorption cross-section of Al<sup>27</sup>.

METHOD

Synchrotron

			Transmission Chamber		64 Fo 1	JOC	
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,P	SPC	THR - 40	C	20-40	EMU-D	1-18	DST

RLX

See following theory paper, Nucl. Phys. 56, 615-(1964)

TABLE 1

The  $\alpha$  coefficient in the angular distribution  $1 + \alpha \sin^2\theta$  of the photoprotons from Mg<sup>24</sup> at the different bremsstrahlung maximum energies

Proton energy (MeV)	$E_{\max} = 23$ MeV	$E_{\max} = 26.5$ MeV	$E_{\max} = 40$ MeV
1.0—3.5	$1.11 \pm 0.44$	$0.04 \pm 0.05$	
3.5—5.7	$0.18 \pm 0.16$	$-0.15 \pm 0.09$	
5.7—7.3	$-0.29 \pm 0.23$	$-0.26 \pm 0.14$	
>7.3	$-0.40 \pm 0.19$	$0.99 \pm 0.42$	

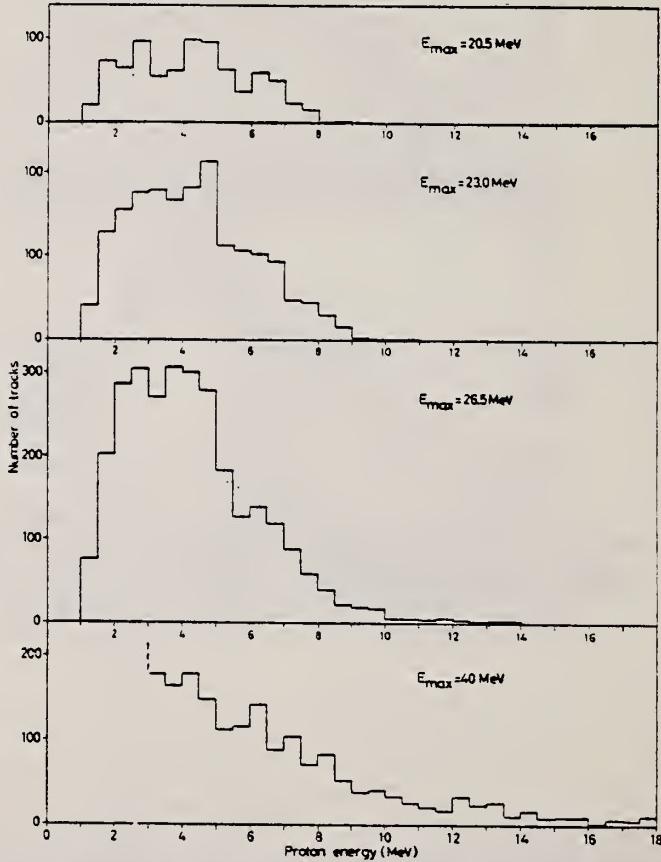


Fig. 2. Proton spectra for maximum bremsstrahlung energies of 20.5; 23, 26.5 and 40 MeV.

## METHOD

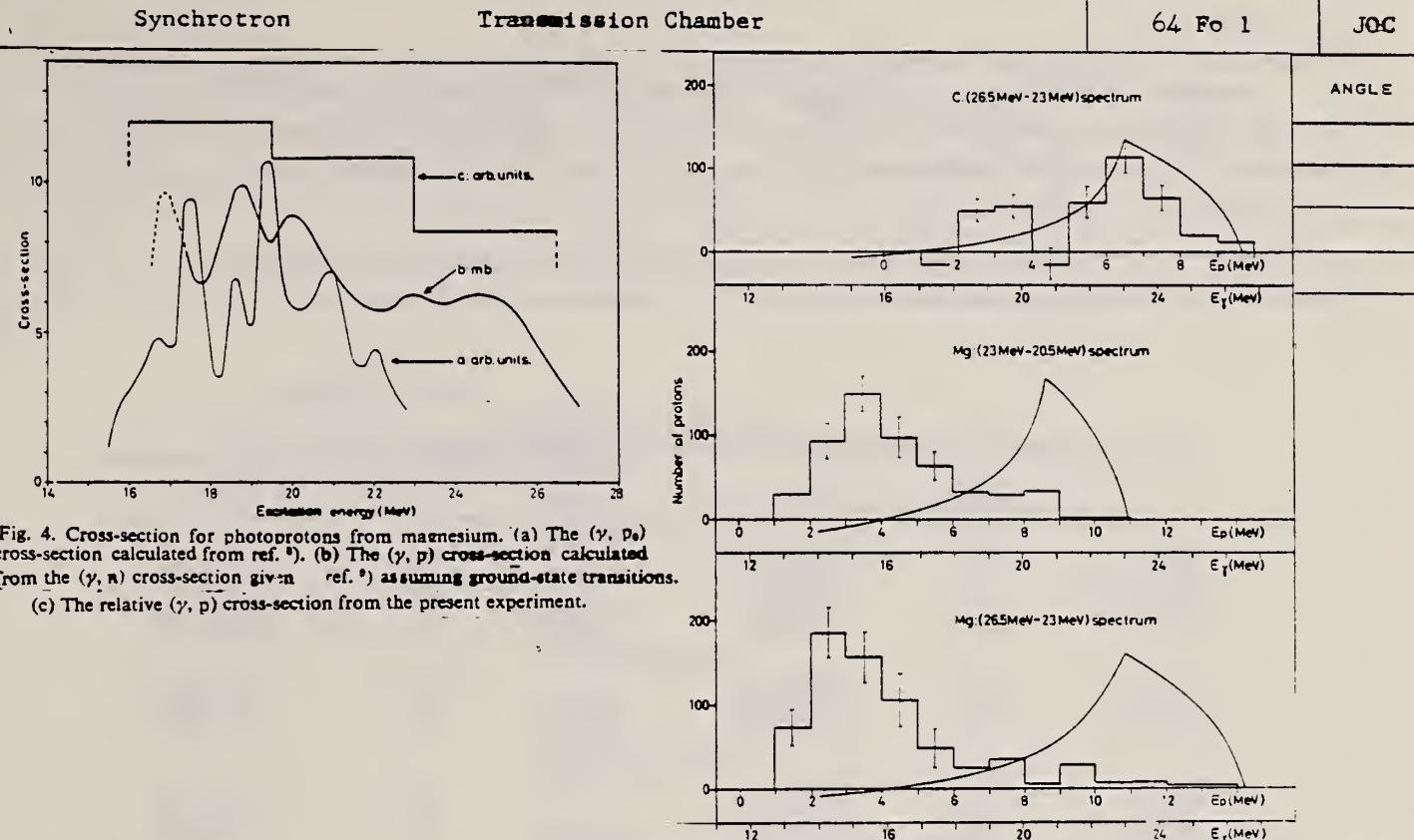


Fig. 4. Cross-section for photoprotons from magnesium. (a) The  $(\gamma, p_0)$  cross-section calculated from ref. <sup>8</sup>. (b) The  $(\gamma, p)$  cross-section calculated from the  $(\gamma, n)$  cross-section given ref. <sup>8</sup> assuming ground-state transitions. (c) The relative  $(\gamma, p)$  cross-section from the present experiment.

Fig. 6. Difference proton spectra between the 23 MeV and the 20.5 MeV exposures and the 26.5 MeV and the 23 MeV exposures for magnesium and carbon. The corresponding photon spectra are also given.

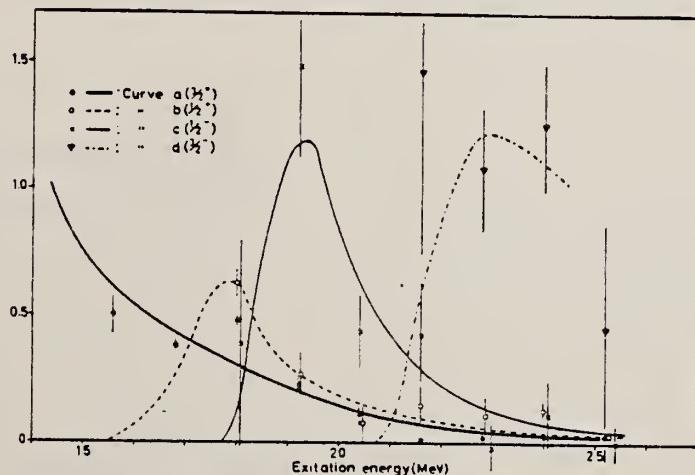


Fig. 7. Branching ratios to (a) the  $\frac{1}{2}^+$  ground state  $[211 \frac{1}{2}]$ , (b) the  $\frac{1}{2}^+$  hole state  $[220 \frac{1}{2}]$  at 2.6 MeV, (c) the  $\frac{1}{2}^-$  hole state  $[101 \frac{1}{2}]$  at 5 MeV, (d) the  $\frac{1}{2}^-$  hole state  $[101 \frac{1}{2}]$  at 8 MeV in  $\text{Na}^{24}$  as a function of the excitation energy of  $\text{Mg}^{24}$ .

METHOD

Linac

REF. NO.

64 Go 3

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	ABX	11	D	40-70	MAG-D		180

FMF

TABLE I. Data on M1 transitions.

$\frac{q}{McV/c}$	Cross section*	Reference	$ \langle J_f    T_1^{\max}(q)    J_i \rangle ^2 (1/q^2)  \langle J_f    T_1^{\max}(q)    J_i \rangle ^2$ $[10^{-3} (10^{-3})]$
15.1-MeV level in C <sup>12</sup>			
Photons	15.1	(2.05 ± 0.27)	8
Electrons	68	(2.0 ± 0.3)	this work
Electrons (160°)	68	(2.6 ± 0.19 <sup>b</sup> )	5
Electrons	93	(2.0 ± 0.3)	this work
Electrons	125	(1.5 ± 0.25)	this work
3.56-MeV level in Li <sup>6</sup>			
Photons	3.56	(0.92 ± 0.19 <sup>b</sup> )	b
Electrons	76	(3.0 ± 0.45)	this work
Electrons	106	(1.55 ± 0.23)	this work
Electrons	136	(0.90 ± 0.14)	this work
11.6-MeV level in Si <sup>28</sup>			
Photons	11.6	(9.8 ± 2.6)	c
Electrons	71.5	(3.5 ± 1.4)	d
Electrons	88.4	(3.0 ± 0.75)	this work
Electrons	129.4	(1.8 ± 0.45)	this work
11-MeV level in Mg <sup>24</sup>			
Photons	11	(13.1 ± 3.8)	c
Electrons	83	(4.4 ± 0.88)	6
Electrons	97	(3.5 ± 0.70)	this work
Electrons	129	(1.8 ± 0.36)	this work

\* In units of  $10^{-27} \text{ MeV-cm}^2$  for photons and  $10^{-21} \text{ cm}^3/\text{sr}$  for electrons.

<sup>b</sup> L. Cohen and R. A. Tobin, Nucl. Phys. 14, 243 (1960).

<sup>a</sup> A. B. de Nercy, Ann. Phys. (Paris) 6, 1379 (1961).

<sup>4</sup> R. D. Edge and G. A. Peterson, Phys. Rev. 128, 2750 (1962).

ELEM. SYM.	A	Z
Mg		

12

## METHOD

REF. NO.

Betatron

64 Is 1

JOC

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XP	ABX	THR - 32	C	15-32	SCI-D	0-3	45°

336

Table 2  
 Measurements results

Element	Maximum cross section (b)	Peak position (MeV)	Peak half-width (MeV)	Integrated cross section $\int_{\text{caE}}^{\infty} \sigma(E) dE$ (MeV, b)
P	0.043	21	10	$0.35 \pm 0.06$
S	0.050	21	9	$0.37 \pm 0.05$
Mg	0.018 0.018	22.5 26.0	11	$0.18 \pm 0.04$

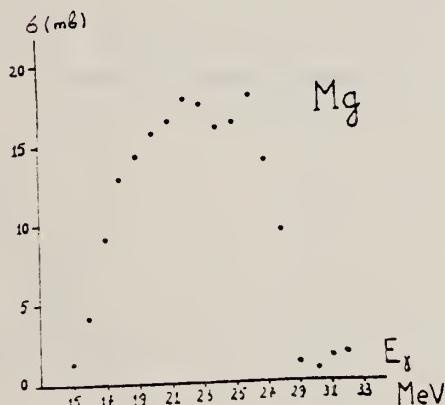


Fig. 2. The  $(\gamma, p)$  cross section for Mg.

METHOD

Synchrotron

REF. NO.

65 Do 2

EGF

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,MU-T	ABX	11 - 30	C	260	MGP-D	10-30	

$$\int_{11}^{30} \sigma dE = 365^{+40}_{-20} \text{ MeV-mb}$$

$$\frac{\int E \sigma dE}{\int \sigma dE} = 21.6 \text{ MeV}$$

$$\sigma_{-1} = 17.9 \text{ mb}$$

$$\sigma_{-2} = 0.95 \text{ mb/MeV}$$

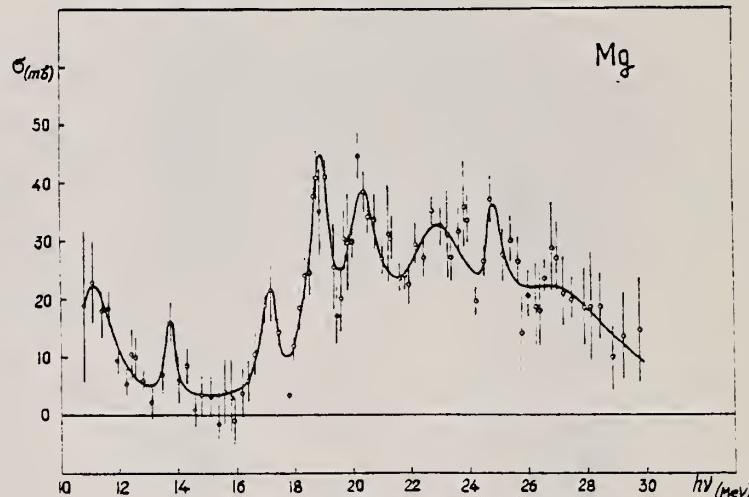


Fig. 2. The nuclear absorption cross section.

TABLE I  
 Parameters of resonance peaks observed in the nuclear absorption cross section

$h\nu_{res}$ (MeV)	11.2	13.8	17.1	18.9	20.4	22.9	24.9	27.0
$\sigma_{max}$ (mb)	21	13	20	37	29	26	20	19
Half-width $\Gamma$ (MeV)	1.5	0.3	0.4	0.8	1.3	2.6	0.6	4.9
$\int \sigma(h\nu) d(h\nu)$ (MeV · mb)	48	7	14	44	57	106	18	146

METHOD				REF. NO.				
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE			
				TYPE	RANGE	TYPE	RANGE	
G, XP	SPC	THR - 31	C	31		SCD-D	3-14	

$$Y(E_p > 3.5 \text{ MeV}) = 10^{-4} \text{ cm}^2/\text{mole MeV.}$$

TABLE I. - Energy levels in  $^{24}\text{Mg}$ .

( $\gamma$ , n) (*)	( $\gamma$ , n) (*)	Total absorption (**)	Total absorption (**)	Our experiment
—	—	—	—	16.3
17	17.5	17	17.5	17.8
—	18.8	18.9	19.2	18.9
19.5	—	—	—	—
—	20	20.3	20	20
21.5	—	—	—	—
23.5	23	23.1	—	—
25.5	25	25.8	—	—

(a) ref. (1)  
 (b) ref. (2)

(c) ref. (14)  
 (d) ref. (15)

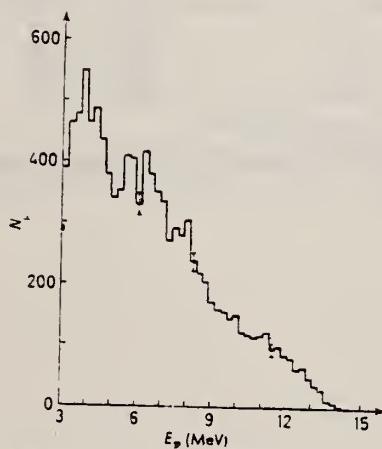


Fig. 2. - Photopion spectrum from Mg.

## METHOD

REF. NO.

Synchrotron; NBS chamber monitor

65 Mi 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,XN	ABX	THR-30	C	THR-30	BF3-I		4PI

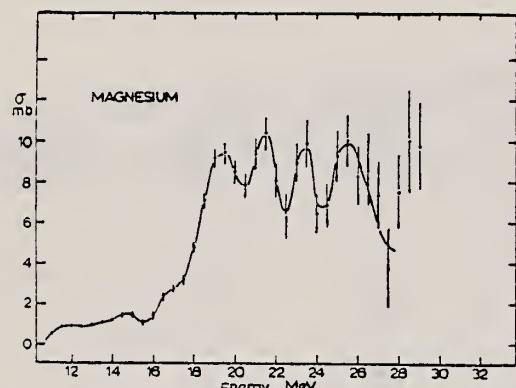
335

FIG. 3. Total photoneutron cross section of magnesium unfolded in 1-MeV intervals.

TABLE I. Isotopic abundance in the samples and threshold energies.

Isotope	Abundance (%)	(γ, n) (MeV)	(γ, pn) (MeV)	(γ, 2n) (MeV)
C <sup>12</sup>	98.89	18.7	27.4	32.4
C <sup>13</sup>	1.11	5.0	20.9	23.7
Mg <sup>24</sup>	78.60	16.6	24.1	
Mg <sup>25</sup>	10.11	7.3	19.0	23.9
Mg <sup>26</sup>	11.29	11.1	23.2	18.4

TABLE III. Energy levels observed in magnesium (MeV).

Present work (γ, n)	Other experiments (γ, n) <sup>a</sup>	Absorption <sup>b</sup>
17.0	17.5	17.0
19.5	18.8	19.0
21.5	20.0	20.0
23.5	23.0	23.0
25.5	25.0	25.0

$$\int_{\text{Th}} \sigma dE = 90.7 \text{ MeV} \cdot \text{mb}$$

<sup>a</sup> Reference 9.<sup>b</sup> Reference 23.

METHOD

Synchrotron; ion chamber monitor

REF. NO.

65 Wy 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, MU-T	ABX	10-70	C	90	SCI-D		+P <sub>1</sub>

41+

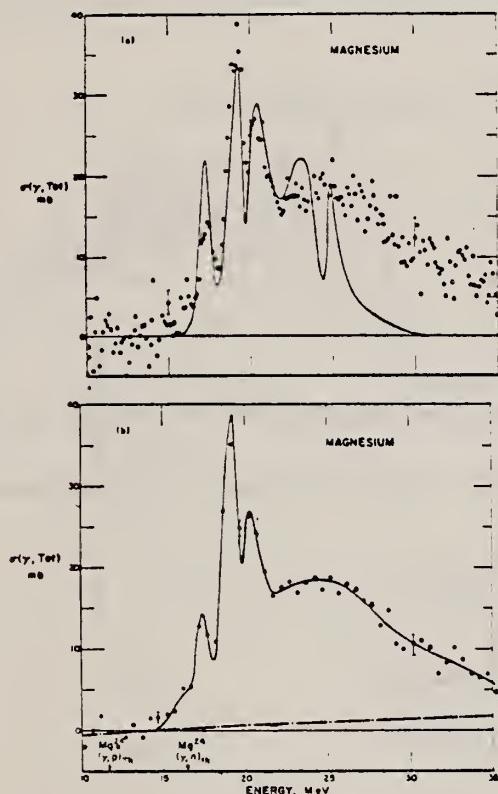


FIG. 13. Magnesium total photonuclear cross section. The solid line in (a) represents the Lebedev data moved up in energy by 375 keV.

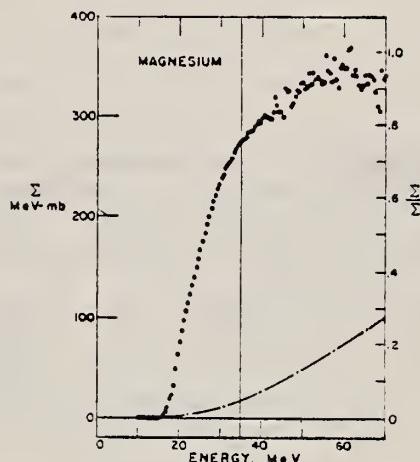
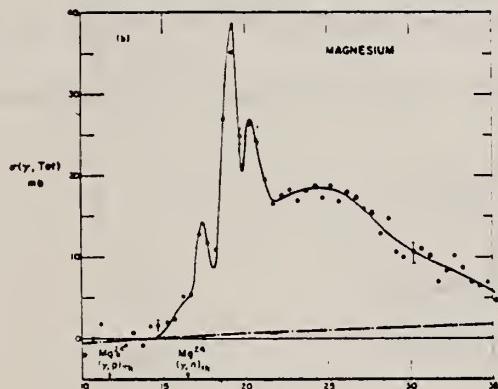


FIG. 14. Magnesium total photonuclear cross section integrated over energy. The dot-dashed line represents the corrected baseline resulting from the introduction of the calculated radiative corrections to the electronic cross sections.

REF. B. S. Dolbilkin, V. A. Zapevalov, V. I. Korin, L. E. Lazareva  
and F. A. Nikolaev  
Izv. Akad. Nauk fiz. 30, 349 (1966)  
Bull. Acad. Sci. USSR-Phys. 30, 354 (1966)

ELEM. SYM. A  
Mg  
Z 12

METHOD REF. NO.  
66 Do 2 EGF

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G-MU-T	ABX	8-30	C	260	MGP-D	6-30	4PI

Resolution 120 keV 10 MeV  
220 keV 20 MeV

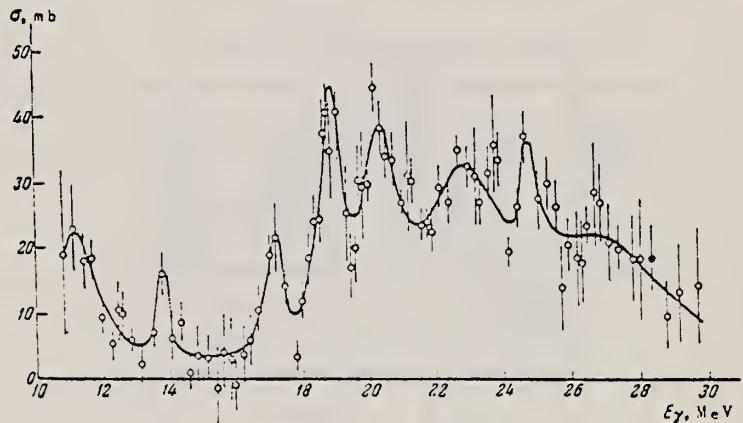


Fig.3. Nuclear absorption cross section of magnesium.

Table 2

Breit-Wigner resonance components of the Mg cross section (Fig.3)

$E_{res'}$ MeV	$\sigma_{max'}$ mb	$\Gamma_{res}$ MeV	$fadE$ MeV·mb	$E_{res'}$ MeV	$\sigma_{max'}$ mb	$\Gamma_{res}$ MeV	$fadE$ MeV·mb
11.2	21	1.5	48	20.4	29	1.3	57
13.8	13	0.3	7	22.9	26	2.6	106
17.1	20	0.4	14	24.9	20	0.6	18
18.9	37	0.8	44	27.0	19	4.9	15

REF.

F. W. K. Firk  
Proc. Gatlinburg Conference 352 (1966)

ELEM. SYM.	A	Z
Mg		12

REF. NO.  
66 Fi 2  
hmg

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XN	SPC	THR-65	C	65	TOF-D	5-40	90

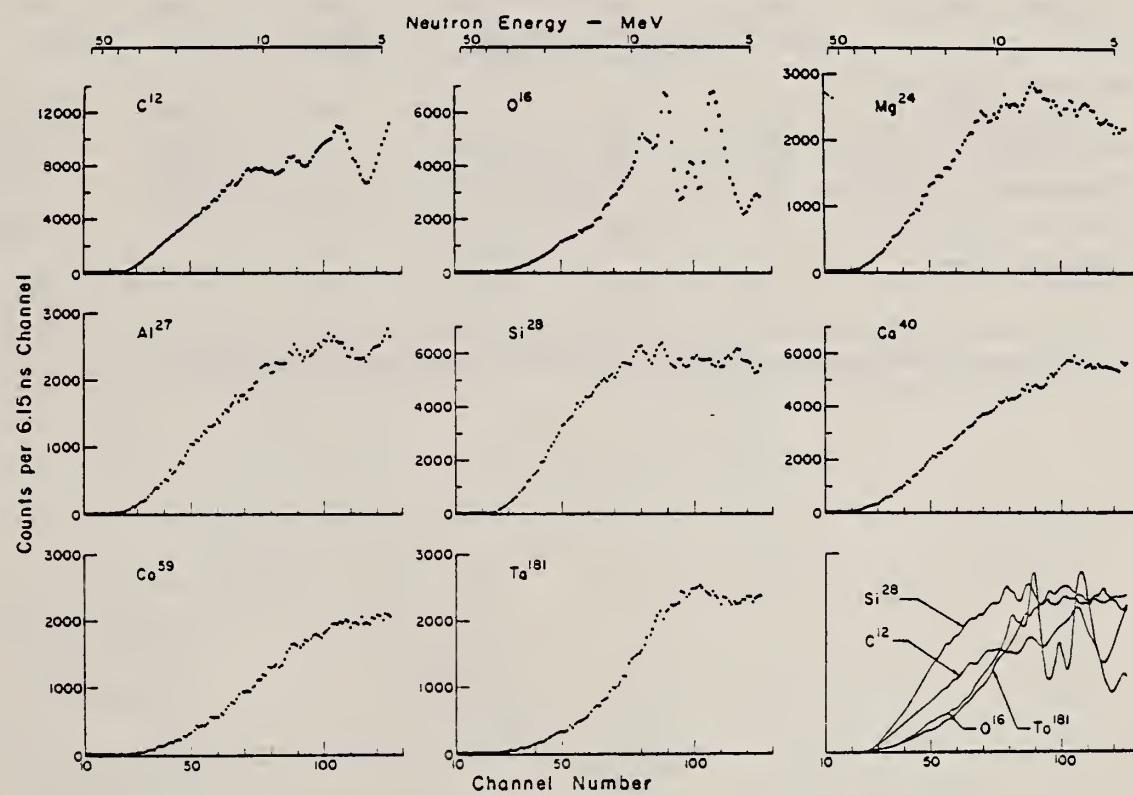


Fig. 1. Observed photoneutron time-of-flight spectra of C, O, Mg, Si, Ca, Co, V, and Ta.

METHOD

Betatron

REF. NO.

66 Ho 3

JDM

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,A	SPC	THR-31	C	31	SCD-D	2-13	130

TABLE I  
 Experimental data and results

Element	Mg	Al	S	Ni	Cu	Zn	Error (%)
target thickness (mg/cm <sup>2</sup> )	0.81	1.54	0.80	2.50	2.68	3.00	5 a)
dose (r)	6190	25400	23200	3880	5840	4220	10
yield absolute ( $10^6/\text{mole} \cdot \text{r}$ ) for $E_m > 3.16 \text{ MeV}$	0.61	0.93	1.46	1.65	0.92	2.42	11 a)
yield relative to Ni	0.36	0.56	0.88	1	0.55	1.43	5 a)
$Y_{\gamma, \alpha}/Y_{\gamma, \text{tot}} (\%)$	9.6	11.4	12.4	7.0	3.2	b)	
nuclear temp. $\theta$ (MeV)	1.43	1.48	1.46	1.04		0.91	10
level density parameter a (MeV <sup>-1</sup> )	5.1	4.8	4.9	8.6		10.8	10

a) For S, the error of the target thickness has been 10 %, of the absolute yield 14 % and of the relative yield 10 %.

b) For Zn  $\sigma_{\gamma, \text{tot}}$  is not known.

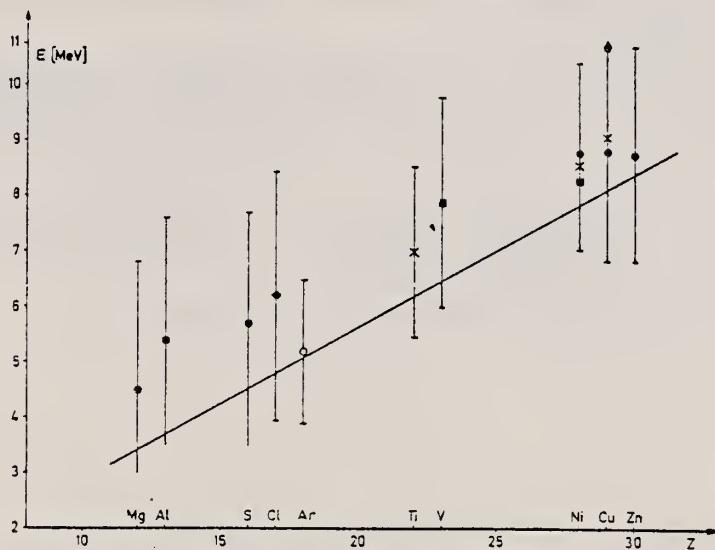


Fig. 4. Position of the peaks in different photoalpha spectra plotted against  $Z$  of the target nuclei.  
 x : Scheer *et al*<sup>10</sup>, ■ : Kregar and Povh<sup>8</sup>, ▲ : Meneghetti and Vitale<sup>9</sup>, ♦ : Erdös *et al*<sup>11</sup>,  
 ○ : Komar *et al*<sup>7</sup>, ● : this work. The signs show the position of the maximum, the bars give the  
 widths at half maximum. The curve shows the height of the Coulomb barrier.

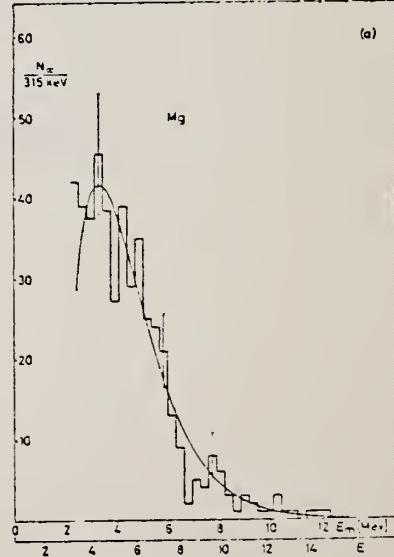


Fig. 3 (a)

REF.

J. M. Loiseaux, J. M. Maison, and M. Langevin  
 J. de Physique 28, 11 (1967)

ELEM. SYM.	A	Z
Mg		12

METHOD

REF. NO.

67 Lo 1

JOC

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G/	ABX	16-32	C	34	NAT-D		DST

TABLEAU I

COEFFICIENT  $a$  DES DISTRIBUTIONS ANGULAIRES

$$W(\theta) = 1 - a \cos^2 \theta$$

$^{16}\text{O}$ .....	$a(19\text{-}25 \text{ MeV}) = 1 \pm 0.1$				
$^{23}\text{Na}$ .....	$a(15\text{-}18 \text{ MeV}) = 0.1 \pm 0.1$	$a(18.5\text{-}23 \text{ MeV}) = 0.4 \pm 0.15$	$a(25\text{-}30 \text{ MeV}) = 0.85 \pm 0.2$		
$^{24}\text{Mg}$ .....	$a(16.5\text{-}20 \text{ MeV}) = 0.3 \pm 0.1$	$a(20\text{-}25 \text{ MeV}) = 0.5 \pm 0.1$	$a(25.5\text{-}32 \text{ MeV}) = 0.5 \pm 0.1$		
$^{28}\text{Si}$ .....	$a(15\text{-}17.5 \text{ MeV}) = 0.87 \pm 0.1$	$a(18\text{-}23 \text{ MeV}) = 0.7 \pm 0.1$	$a(25.5\text{-}32 \text{ MeV}) = 0.5 \pm 0.1$		
$^{39}\text{K}$ .....	$a(14.5\text{-}18.5 \text{ MeV}) = 0.5 \pm 0.1$	$a(19\text{-}24.5 \text{ MeV}) = 1 \pm 0.1$	$a(25\text{-}32 \text{ MeV}) = 1 \pm 0.1$		

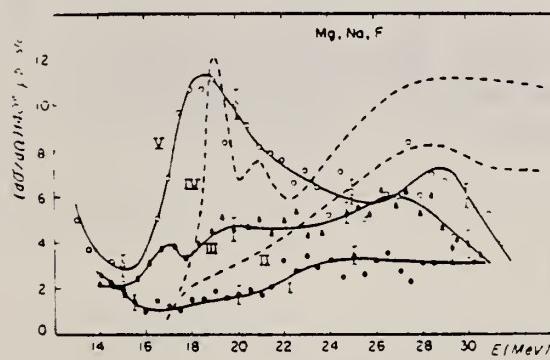


FIG. 6.

Sections efficaces différentes de diffusion à 110° pour  $^{19}\text{F}$  (I),  $^{23}\text{Na}$  (III) et Mg (V).

Section efficace prévue par la relation de dispersion pour  $^{23}\text{Na}$  (courbe II) et Mg (courbe IV).

G. A. Savitskii, N. G. Afanas'ev, I. S. Gul'karov, V. M. Khvastunov,  
 A. A. Khomich, and N. G. Shevchenko  
*Yad. Fiz.* 7, 1181 (1968)  
*Sov. J. Nucl. Phys.* 7, 705 (1968)

ELEM. STM.

Mg

12

METHOD

REF. NO.

68 Sa 1

HMG

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	FMF	1-8	D	100-260	MAG-D		

Observed inelastic scattering peaks at  
 $1.4 \pm .2$ ,  $4.1 \pm .2$ ,  $6.0 \pm .3$ ,  $6.9 \pm .3$ ,  $7.6 \pm .3$  MeV.  
 Results compared with the prediction of the  $\alpha$ -particle model.

3 PEAKS 1.4-6.0

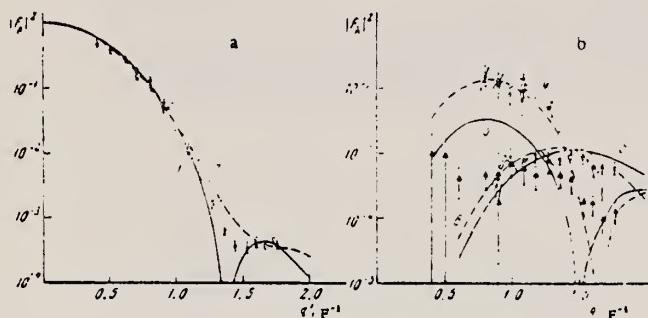


FIG. 1. Form factors for scattering of electrons by the nucleus  $Mg^{24}$ : a – elastic scattering form factor; b – form factors corresponding to excitation of the levels 1.37 MeV ( $2^+$ ) – ○; 6.0 MeV ( $4^+$ ) – X; and doublet 4.1 MeV ( $2^+$  and  $4^+$ ) – ▲; the curves are calculated according to the  $\alpha$ -particle model.

METHOD

REF. NO.

69 Sa 2

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	FMF	1-8 (1.4-7.6)	D	99-229	MAG-D	99-229	DST

B(EL) 1-8 MEV

Table 2

Squared form factor for inelastic scattering of electrons with excitation of levels in  $^{24}\text{Mg}$

$Q = 1.37 \text{ MeV}$	$(4.1 \pm 0.2) \text{ MeV}$		$(6.0 \pm 0.2) \text{ MeV}$		$(6.9 \pm 0.3) \text{ MeV}$		$(7.6 \pm 0.3) \text{ MeV}$		
	$I_{\text{fermi}}$	$F_{\lambda}^2, 10^{-4}$							
0.804	161 ± 68	0.409	9.8 ± 9.8	0.899	6.5 ± 3.5	0.409	5.2 ± 1.3	0.899	11.1 ± 6.6
0.804	147 ± 46	0.509	9.4 ± 9.4	0.902	4.8 ± 3.0	0.509	5.0 ± 1.4	0.902	11.5 ± 3.9
0.902	101 ± 32	0.609	4.0 ± 2.0	0.903	8.5 ± 3.3	0.609	3.1 ± 1.1	0.903	15.1 ± 3.9
0.903	114 ± 35	0.804	4.7 ± 2.0	1.09	7.9 ± 2.3	0.706	2.3 ± 0.8	1.09	19.6 ± 4.7
0.904	131 ± 41	0.899	5.1 ± 2.6	1.18	9.6 ± 2.0	0.707	2.2 ± 0.7	1.18	21 ± 5
0.903	79.2 ± 24.6	0.902	1.8 ± 1.6	1.27	8.6 ± 2.3	0.804	1.4 ± 0.4	1.27	15.9 ± 3.7
1.08	64.2 ± 26.4	0.993	6.8 ± 2.1	1.36	8.1 ± 1.6			1.36	15.3 ± 3.4
1.09	113 ± 24	1.09	5.7 ± 2.0	1.44	10.0 ± 1.8			1.44	10.5 ± 2.3
1.09	90.0 ± 18.9	1.09	5.9 ± 3.0	1.53	8.3 ± 1.4			1.53	12.1 ± 2.7
1.09	137 ± 28	1.18	4.6 ± 1.9	1.60	6.3 ± 1.3			1.60	7.8 ± 2.0
1.18	60.6 ± 12.7	1.27	7.7 ± 2.7	1.67	6.3 ± 1.5			1.67	6.4 ± 1.7
1.27	52.2 ± 11.0	1.36	4.5 ± 1.6	1.76	6.1 ± 1.4			1.76	4.8 ± 1.4
1.28	50.4 ± 13.1	1.44	3.8 ± 1.4						
1.36	37.3 ± 5.7	1.53	4.8 ± 0.6						
1.44	49.0 ± 4.2	1.60	4.7 ± 0.5						
1.63	9.92 ± 1.63	1.67	0.65 ± 0.33						
1.60	5.31 ± 1.62	1.70	1.20 ± 0.43						
1.67	2.60 ± 0.52								

Table 5

Characteristics of some electron-excited transitions in  $^{24}\text{Mg}$

Method	Parameters and method of determination	$6.0 \pm 0.2 \text{ MeV}, \lambda = 4$	$6.0 \pm 0.3 \text{ MeV}, \lambda = 1$	$7.6 \pm 0.3 \text{ MeV}, \lambda = 3$
1	$\beta_{\lambda}, 10^{-3}$			
	$B(E\lambda, I_i \rightarrow I_f), e^2 \text{fermi}^2$	$(4.1 \pm 0.9) \cdot 10^4$	$2.8 \pm 0.4$	$(2.4 \pm 0.7) \cdot 10^3$
	$G$	$15.0 \pm 3.2$	$1.7 \pm 0.3$	$10.3 \pm 3.0$
2	$A_{\lambda}, \text{fermi}^{\lambda-2}$	$0.61 \pm 0.04$	$1.41 \pm 0.07$	$0.84 \pm 0.04$
	$B_{\lambda}, \text{fermi}^2$	$0.38 \pm 0.05$	$1.00 \pm 0.14$	$0.32 \pm 0.04$
	$B(E\lambda, I_i \rightarrow I_f), e^2 \text{fermi}^{2\lambda}$	$(6.6 \pm 0.7) \cdot 10^4$	$1.20 \pm 0.12$	$(1.55 \pm 0.12) \cdot 10^3$
	$G$	$24.6 \pm 2.6$	$0.73 \pm 0.08$	$6.6 \pm 0.6$
	$R_{\text{trans}}, \text{fermi}$	$4.76 \pm 0.12$	$4.05 \pm 0.17$	$4.18 \pm 0.08$

[ over ]

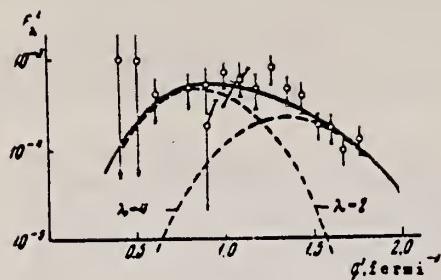


Fig.4

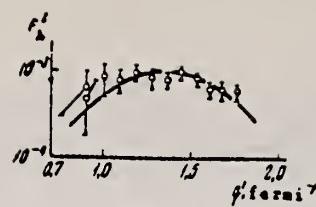


Fig.5

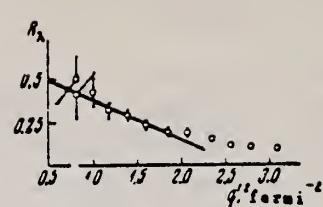


Fig.6

Fig.4. Squared form factor for excitation of  $^{24}\text{Mg}$  levels at 4.12 and 4.23 MeV, as a function of  $q'$ . Solid curves - calculated by method 1 for a  $\lambda = 1$  plus  $\lambda = 4$  multipole mixture and fitted to the experimental points ( $\beta_2 = 0.0112$  and  $\beta_4 = 0.0566$ ). Dashed curves - contributions of the individual multipoles.

Fig.5. The same as Fig.4, but for the 6.0 MeV level. ( $\lambda = 4$ ,  $\beta_4 = 0.258$ ).

Fig.6.  $R_\lambda$  (Ref. 8) as a function of  $q'^2$  for the 6.0 MeV level in  $^{24}\text{Mg}$ . The straight line is described by the equation  $R_\lambda = A\lambda \cdot (1 - B_\lambda q'^2)$  with  $\lambda = 4$ ,  $A_\lambda = 0.61$ , and  $B_\lambda = 0.38$  fermi $^2$ .

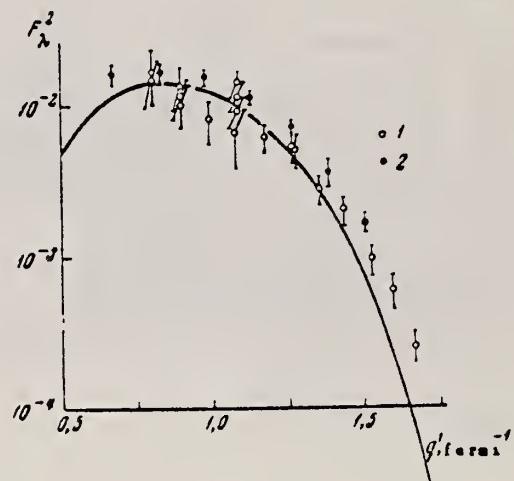


Fig.3

Fig.3. Squared form factor for inelastic scattering of electrons by  $^{24}\text{Mg}$  with excitation of the 1.37 MeV level, as a function of  $q'$ : 1 - our data; 2 - Helm's data<sup>4</sup>. The curve is a least-squares fit to our experimental points, calculated by method 1 ( $\lambda = 2$ ,  $\beta_2 = 0.35$ ).

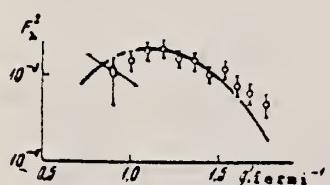


Fig.7. The same as Fig.4 but for the 7.6 MeV level ( $\lambda = 3$ ,  $\beta_3 = 0.167$ ).

METHOD

REF. NO.

71 Fu 2

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,XN	ABX	THR-29	D	10-29	BF3-I		4PI

14 LEVEL FIT 342

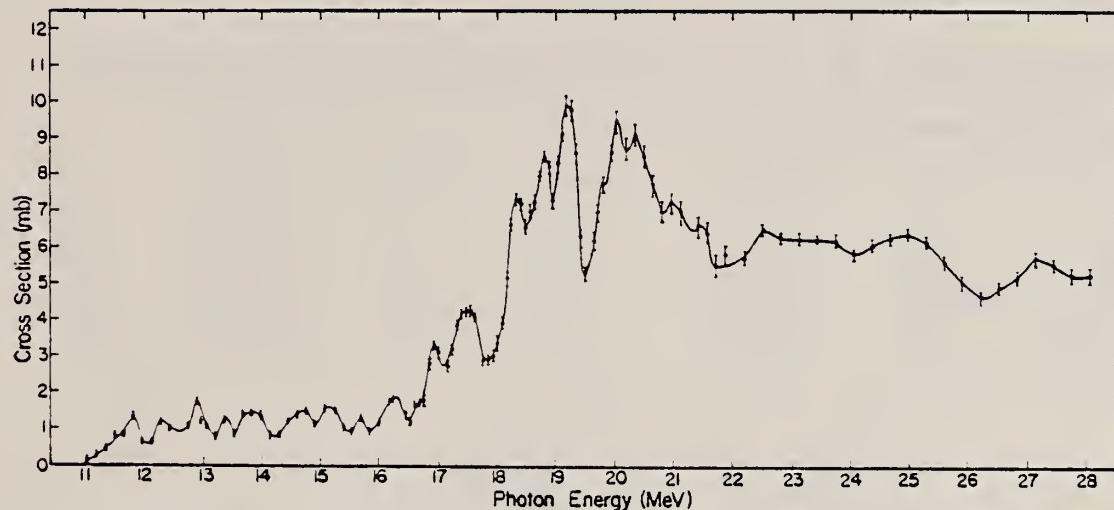


FIG. 8. Natural magnesium total cross section  $\sigma((\gamma, n) + (\gamma, pn) + (\gamma, 2n))$  showing detailed structure. The solid line is merely to guide the eye through the data points.

TABLE II. Integrated cross sections of magnesium isotopes.

Isotope	$\int_{E_{thr}}^{28} \sigma(\gamma, n_{tot}) dE$ (MeV mb)	$\int_{E_{thr}}^{28} \sigma(\gamma, 2n) dE$ (MeV mb)
$^{24}\text{Mg}$	50	...
$^{26}\text{Mg}$	226	68
Natural magnesium	76	...

METHOD	REF. NO.				
	71 Sa 2				
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
G, P	ABX	THR-250	C 20-250	ACT-I	4PI

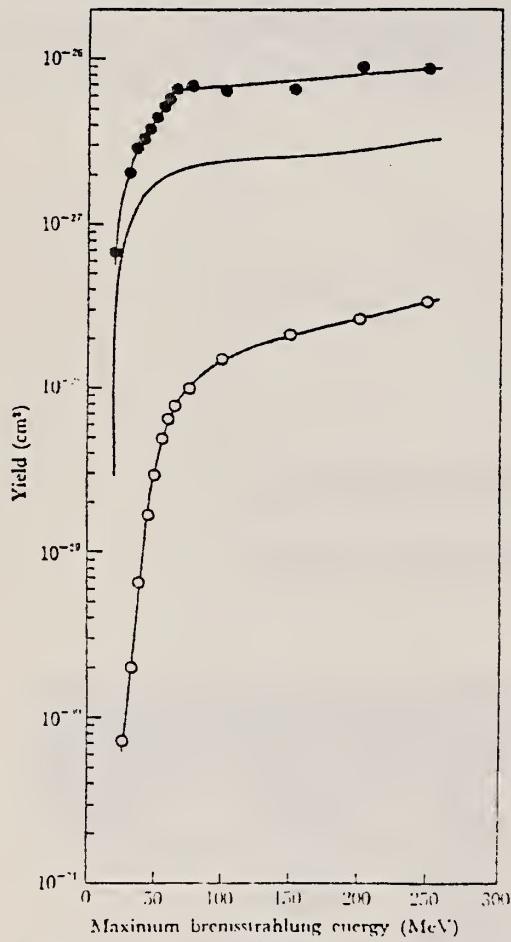


Fig. 3. The yield curves for the reactions  $^{22}\text{Mg}(\gamma, p)^{21}\text{Na}$ ,  $^{27}\text{Al} \rightarrow ^{21}\text{Na}$ , and  $^{12}\text{C}(\gamma, n)^{11}\text{C}$  as a monitor.

Table 1  
Differential cross sections ( $\mu\text{b}/\text{sr}$ ) for elastic scattering from C and Mg targets at an angle of  $140^\circ$ . The theoretical values include the combined effect of NT, NR and D scattering; The R contribution was ignored. The values for pure NT scattering are also given.

E (keV)	C(Z = 6)			Mg(Z = 12)		
	Experiment	Theory	Thomson	Experiment	Theory	Thomson
5516	0.17 ± 0.04	0.16	0.17	0.64 ± 0.15	0.61	0.67
5752	0.20 ± 0.06	0.15	0.17	0.66 ± 0.15	0.61	0.67
6465	0.17 ± 0.04	0.15	0.17	0.64 ± 0.15	0.59	0.67
6517	0.16 ± 0.04	0.15	0.17	0.63 ± 0.15	0.59	0.67
6874	0.18 ± 0.04	0.15	0.17	0.59 ± 0.15	0.58	0.67
7163	0.16 ± 0.04	0.14	0.17	0.50 ± 0.15	0.57	0.67

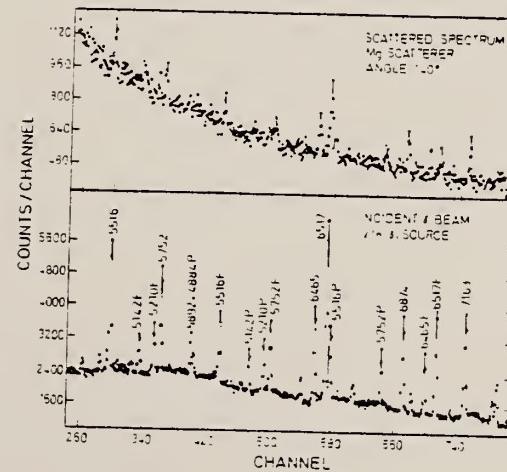


Fig. 1. High-energy part of the elastic scattering spectrum from a Mg target at  $140^\circ$  as measured by a  $40 \text{ cm}^3$  Ge(Li) detector, and of the incident  $V(n, \gamma)$  spectrum. Lines indicated by P and F denote photopeaks and first-escape peaks. Other lines denote double-escape peaks.



MG  
A=24

MG  
A=24



Elem. Sym.	A	Z
Mg	24	12

Method  $BF_3$  counters; 24 MeV Bremms. betatron.

Ref. No.  
55 Na 1 EGF

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$(\gamma, xn)$	9.3 - 24	19.5	7-8	0.055 MeV-mb		$E_{th} = 16.6$ MeV; $\sigma_{max} = 8.4$ mb. No corrections. [NOTE: Figure 1 - "KBM" - Katz, Baker, Montalbetti, Can. J. Phys. 31, 250 (1953).]

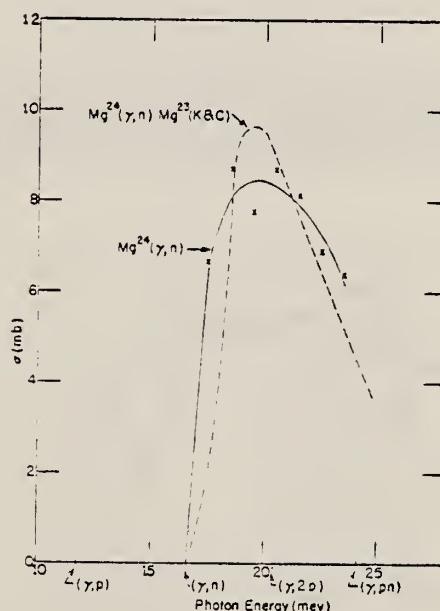


FIG. 1.  $(\gamma, n)$  cross section for  $Mg^{24}$ . The ordinate scale is in millibarns ( $10^{-27}$  cm $^2$ ). The locations of the thresholds for various reactions are indicated by arrows. The crosses are the points calculated from the yield data. The solid curve is drawn to fit the points. The dashed curve represents results previously reported by others for  $Mg^{24}(\gamma, n)/Mg^{24}$  by the residual activity method (see reference 8).

Katz, Baker, and Montalbetti, Can. J. Phys. 31, 250 (1953).

METHOD

REF. NO.

56 He 3

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR		ANGLE
			TYPE	RANGE	TYPE	
E.E./	FMF	1-7	D	187	MAG-D	DST

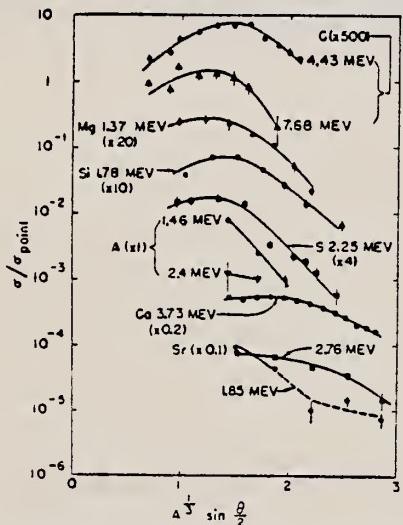


FIG. 3. Inelastic angular distributions (observed cross section divided by Feshbach point-charge cross sections). The results of Hahn *et al.* (reference 8) for Ca and of Fregeau and Hofstadter (reference 11) are included for comparison.

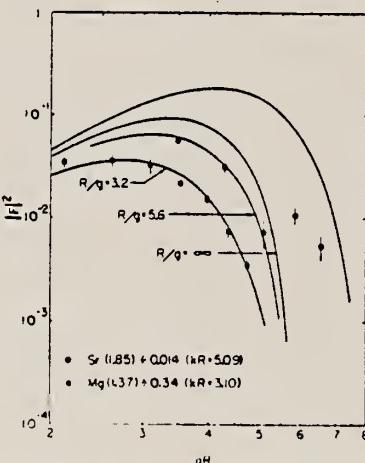


FIG. 6. Comparison of typical experimental and calculated squared inelastic form factors. Both the Sr (1.85 Mev) and Mg (1.37 Mev) are known to be  $2\pm$  levels. The calculated curves are for a "smeared  $\delta$ -function" transition charge density (see Sec. V) with values of  $R/g$  taken from the elastic results. The abscissae for the experimental data are scaled by values of  $R$  taken from the elastic results [Table III (a)]. Shown for comparison (upper curve) is a squared form factor calculated from a quadrupole transition charge density whose radial dependence is constant for  $r < R$ , zero for  $r > R$ . This would give a poorer fit to the data than the  $\delta$ -function distribution, indicating that the quadrupole vibrational mode is approximated better by a transverse wave in an incompressible nuclear fluid than by some sort of a compressional body wave.

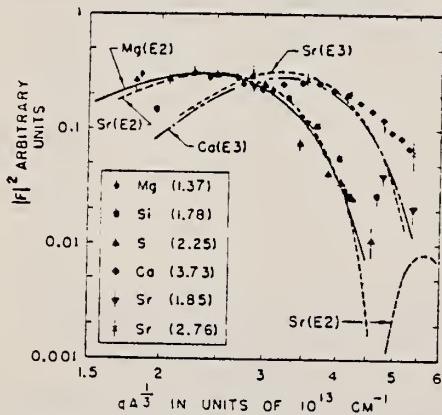


FIG. 7. Inelastic "universal curves." A composite plot of inelastic data from Mg, Si, S, Ca, and Sr against  $q^{(1)}$ . The various form factors are arbitrarily normalized to minimize the spread of points. The point from sulfur and the point from silicon which seem to deviate from the "universal curve" are assumed to contain undetected experimental errors. The curves labeled Mg(E2), Sr(E2), Ca(E3), and Sr(E3) are calculated for electric-quadrupole and octupole transitions using the "smeared  $\delta$ -function" transition charge densities of Sec. V, and are arbitrarily normalized.

METHOD

REF. NO.

58 Bu 1

EGF

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, G	LFT	1	D	1	SCI-D	1	4PI
		1.38 MeV					

$$\Gamma \geq 3.2 \times 10^{-4} \text{ eV.}$$

Lifetime by Doppler recoil method. Used recoil from 2.76 MeV  $\gamma$ .

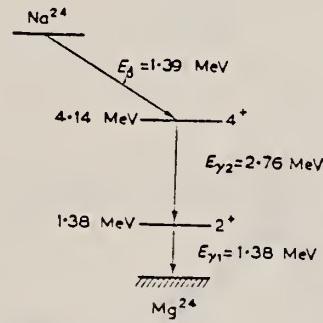


FIG. 1.—The decay scheme of  $^{24}\text{Na}$ .

METHOD

REF. NO.

60 Bu 2

EGF

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	10.5	C		NAI-D		DST

x = scattering target thickness

y = absorber thickness

Peak absorption cross section  $7 \pm 2$  barns.

Ground state radiation width  $180 \pm 50$  eV.

Total width  $1.7 \pm 0.4$  keV.

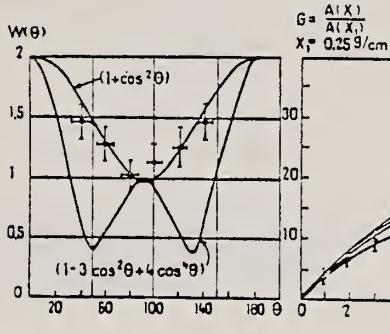


Fig. 1.

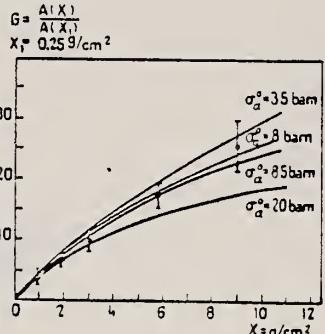


Fig. 2.

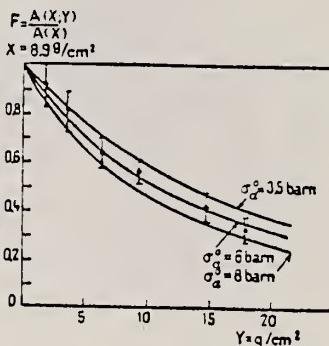


Fig. 3.

METHOD

REF. NO.

60 Bu 3

EGF

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	10	C	23	NAI-D		DST

Includes inelastic to 1st excited state.

$$\int \sigma dE = 1.98 \pm 0.4 \text{ MeV-mb}$$

$$\Gamma_Y = 110 \pm 30 \text{ eV}$$

$$\Gamma = 1 \pm .3 \text{ keV}$$

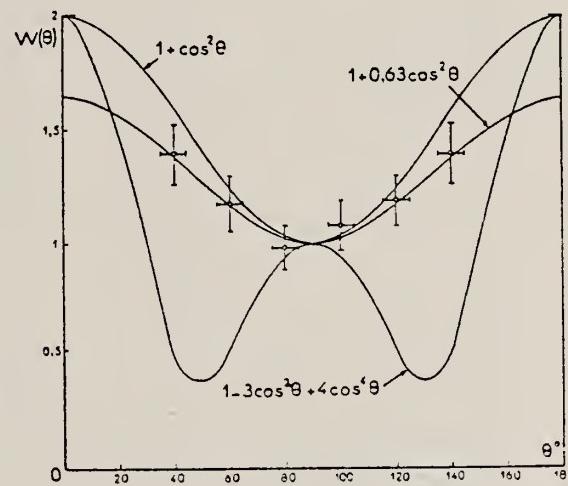


Fig. 4.

Elem. Sym.	A	Z
Mg	24	12

Method 25 MeV betatron; activation; 2 NaI in coinc. to count annihilation radiation of  $\beta^+$  from Mg<sup>25</sup>.

Ref. No.  
 60 Ki 1      JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes	319
( $\gamma$ , n)	Bremss. 16.6-25	$17.2 \pm 0.2$ $19.2 \pm 0.2$				$\sigma(\gamma, n) (19.2 \text{ MeV}) = 6.7 \text{ mb}$  Lower $\sigma(\gamma, n)$ value [9.8 mb, Katz and Cameron, Phys. Rev. <u>84</u> , 1115 (1951); 8.4 mb, Nathens and Yergin, Phys. Rev. <u>98</u> , 1296 (1955) - our reference (55 Na I)] attributed to use of Leiss and Penfold data analysis instead of photon difference method.	

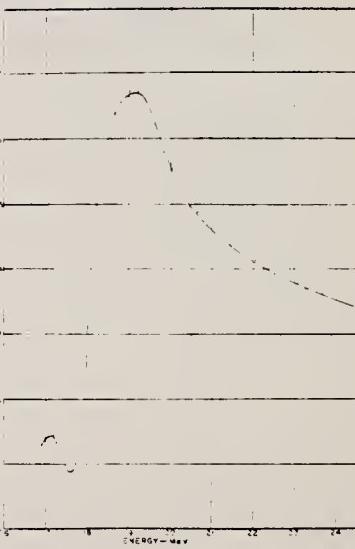


Fig. 5 Cross section for Mg<sup>24</sup>( $\gamma$ , n)Mg<sup>25</sup>

Elem. Sym.	A	Z
Mg	24	12

Method Protons from Bartol-ONR generator; ( $p, p'\gamma$ ), etc. reactions for  $\gamma$  source; ring scatterer; NaI.

Ref. No.  
 60 Me 1 JHH

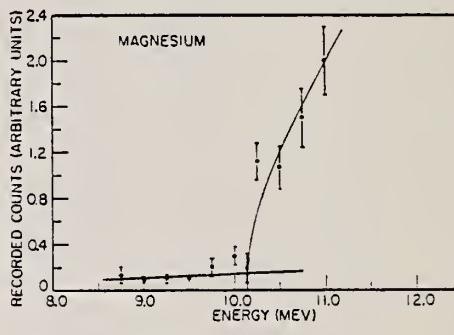
Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$(\gamma, \gamma)$	1.37		$4.2 \pm 1.5 \times 10^{-4}$ ev		$2^+$	Assumed $f(\theta) = 1.25 - 3.75 \cos^2 \theta + 5 \cos^4 \theta$ , corresponding to 0-2-0 spin sequence.

Elem. Sym.	A	Z
Mg	24	12

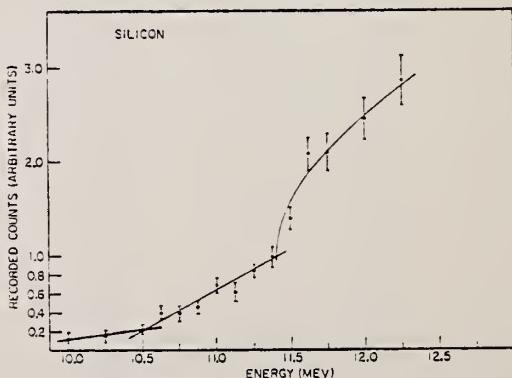
Method Betatron; Mg absorber and scatterer; NaI

Ref. No.  
60 To 1 JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$Mg^{24}(\gamma, \gamma)$	Bremss. 13.1		$4.80^{+1.56}_{-1.43}$ eV		1	$E_{th} = 10.15 \pm 0.06$ MeV Detector at $118^\circ$ .



(a)



(b)

FIG. 4. Thresholds for the levels in Mg and Si.

Method	Ref. No.
Tandem accelerator; NaI	61 Go 1

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$\text{Na}^{23}(p,\gamma)$	2.6-11.4	17.4	$\Gamma_p = 4.9 \text{ MeV}$			$E_{p_0} = \sim 6 \text{ MeV}$ $E_{p_0} \sim 9 \text{ MeV}$
		20.6	$= 4.9 \text{ MeV}$			

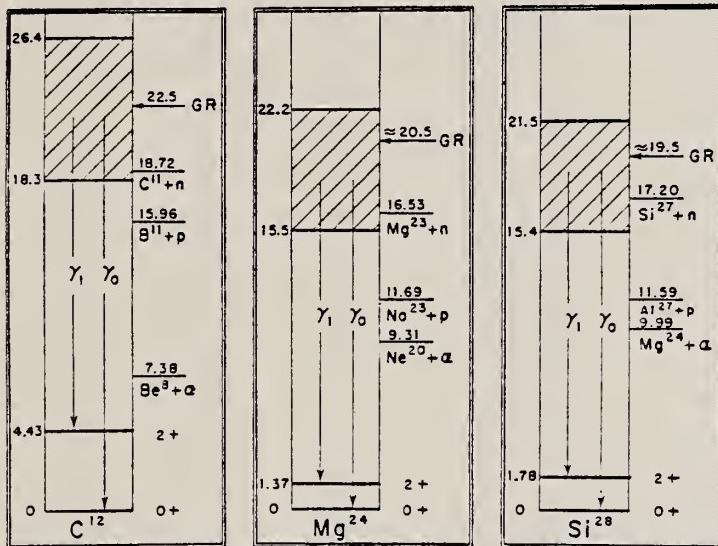


Fig. 1. Partial energy level diagrams for  $\text{C}^{12}$ ,  $\text{Mg}^{24}$  and  $\text{Na}^{23}$  showing the region of excitation energy covered (shaded), the positions of the first excited states and the energies at which each nucleus becomes unstable against neutron, proton and alpha particle emission. The approximate position of the peak of the giant resonance (GR) is also indicated.

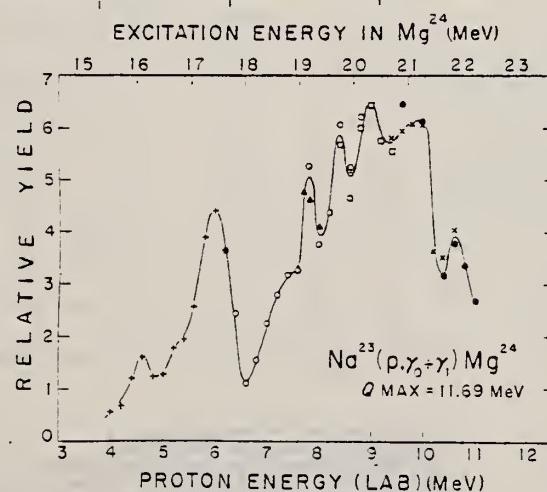


Fig. 19. The combined yield of gamma rays leading to the ground and first excited state of  $\text{Mg}^{24}$  resulting from proton capture in  $\text{Na}^{23}$  and measured at  $90^\circ$  to the incident beam. The different symbols on the yield curve represent separate runs. The abscissa is marked both in terms of the incident laboratory proton energy and in excitation energy in the compound nucleus  $\text{Mg}^{24}$ .

Elem. Sym.	A	Z
Mg	24	12

Method 4 MeV electron Van de Graaff; brems.; nuclear resonance scattering, ring scatterer; NaI	Ref. No. 62 Bo 6	JHH
------------------------------------------------------------------------------------------------	---------------------	-----

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$Mg^{24} (\gamma, \gamma)$	Bremss. 0 - 4					

TABLE 2  
 Comparison of mean lifetime measurements

Nucleus	Energy	%	Spins	$g$	$\Gamma_s/\Gamma$	$W'(\theta)$	$\tau \times 10^{14}$ sec	This work	Other
Li <sup>4</sup>	3.56	7	$1^+ - 0^-$	$\frac{1}{2}$	(1)	1	0.012	$0.0072 \pm 0.0015$ (a)	
								$0.0103 \pm 0.001$ (a)	
Be <sup>11</sup>	2.14	81	$\frac{1}{2}^+ - \frac{1}{2}^+$	$\frac{1}{2}$	1	1	0.53	0.47	$\pm 0.06$ (a)
Al <sup>27</sup>	2.21	100	$\frac{1}{2}^+ - \frac{1}{2}^+$	$\frac{1}{2}$	(1)	1	3.2	2.7	$\pm 0.3$ (a)
Al <sup>27</sup>	1.01	100	$\frac{1}{2}^+ - \frac{1}{2}^+$	$\frac{1}{2}$	0.98	1	520	170	$\pm 50$ (a)
Si <sup>28</sup>	1.78	92	$0^+ - 2^+$	$\frac{1}{2}$	1	0.63	88	73	$\pm 22$ (a)
Si <sup>28</sup>	2.24	95	$0^+ - 2^+$	$\frac{1}{2}$	1	0.63	26	$\approx 16$	(a)
Mg <sup>24</sup>	1.37	78.6	$0^+ - 2^+$	$\frac{1}{2}$	1	0.63	220	155	$\pm 40$ (a)
Mg <sup>24</sup>	1.61	25	$\frac{1}{2}^+ - \frac{1}{2}^+$	$\frac{1}{2}$	(1)	1	3.6	2.5	$\pm 0.6$ (a)
Cu <sup>63</sup>	0.983	69	$\frac{1}{2}^+ - \frac{1}{2}^+$	$\frac{1}{2}$	1	0.92	230	72	$\pm 18$ (a)
Cu <sup>63</sup>	0.67	69	$\frac{1}{2}^+ - \frac{1}{2}^+$	$\frac{1}{2}$	1	1	100	31	$\pm 15$ (a)

The factor  $g$  equals  $(2I+1)(2I_0+1)^{-1}$ .

- (10) R. C. Helms, Phys. Rev. 149 (1962) 1468
- (11) S. Vugman, L. Marwood and R. Meath, IDO-16878
- (12) Leslie Cohen and Raich Toben, Nuclear Physics 14 (1959) 243
- (13) W. C. Barber, F. Berthold, G. Fricke and F. E. Gudnia, Phys. Rev. 120 (1960) 2128
- (14) F. E. Metzger, C. P. Swann and V. K. Rasmussen, Phys. Rev. 110 (1958) 906
- (15) F. E. Metzger, C. P. Swann and V. K. Rasmussen, Nuclear Physics 16 (1960) 568
- (16) S. Oser and A. Schwarzschild, Phys. Rev. Lett. 3 (1958) 384
- (17) V. K. Rasmussen, F. R. Metzger and C. P. Swann, Phys. Rev. 123 (1961) 1348
- (18) J. B. Cummings, A. Schwarzschild, A. W. Sunyar and N. T. Porile, Phys. Rev. 120 (1960) 2128
- (19) T. Rothan, F. R. Metzger and C. P. Swann, Nuclear Physics 22 (1961) 505

Elem. Sym.	A	Z
Mg	24	12

Method Cockcroft-Walton generator; NaI

Ref. No.  
 62-G1 1

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
(p, $\gamma$ )	300-750 kev	12.18				<p><math>E_p = 511</math> kev.  <math>P_0</math></p> <p>6% of decays are by this ground state transition.</p> <p><math>E_{p_0}</math> resonances also at 308, 591, 676, 738 and 743 kev, but <math>\gamma_0</math> transitions <math>\leq 2.9\%</math>.</p> <p>Detector at 55°.</p>

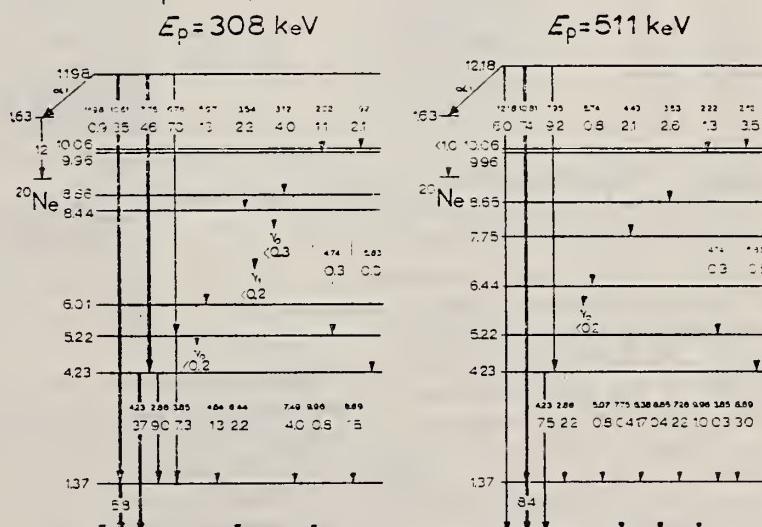


Fig. 4. Decay schemes of the  $^{23}\text{Na}(p,\gamma)^{24}\text{Mg}$  resonances at  $E_p = 308$  and 511 keV.

Elem. Sym.	A	Z
Mg	24	12

Method

[proton source not given]; NaI

Ref. No.	JHH
62 Pr 1	

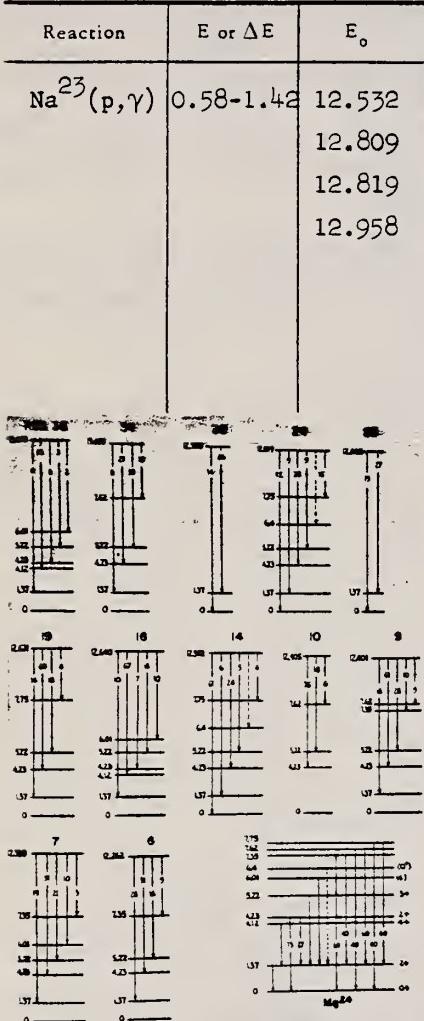


Fig. 1: Relative intensities and proposed cascades for 12 resonances in the reaction

$\text{Na}^{23}(\text{p}, \gamma)\text{Mg}^{24}$ . The numbering of the resonances is that proposed in ref. 6 [Prosser et al., Phys. Rev. 104, 369 (1956)]; the corresponding proton bombarding energies are listed in Table I. The dashed lines represent transitions the existence of which are uncertain at that resonance.

TABLE I. Relative intensities of the  $\gamma$  rays observed at the resonances in the  $\text{Na}^{23}(\text{p}, \gamma)\text{Mg}^{24}$  reaction. The relative intensities, with their standard errors, are given parenthetically following the energies of the  $\gamma$  rays and are in arbitrary units based on 100 for the strongest high-energy  $\gamma$  ray in the spectrum. The energies of the  $\gamma$  rays whose presence in the spectra are less certain or which were not fitted into a decay scheme are shown in italics.

Resonance	Proton energy (kev)	Excitation energy (Mev)	$\gamma$ -ray energy (Mev) and relative intensity
6	594	12.262	10.89 (56±5); 8.03 (100±5); 7.04 (32±5); 6.03 (9±2); 4.90 (8±2); 4.23 (80±4); 3.85 (46±4); 2.86 (31±6); 1.37 (144±20)
7	675	12.338	10.97 (30±4); 8.80 (4±2); 8.10 (100±8); 7.35 (13±5); 7.11 (41±7); 6.32 (11±4); 5.98 (15±4); 4.98 (19±4); 4.64 (6±3); 4.23 (76±4); 3.85 (40±4); 2.86 (30±4); 1.37 (120±4)
9	740	12.401	11.03 (42±5); 9.2 (20±6); 8.8 (13±4); 8.17 (100±5); 7.62 (13±6); 7.35 (27±8); 7.18 (64±8); 6.30 (10±4); 5.98 (13±5); 5.05 (23±4); 4.78 (13±4); 4.23 (84±9); 3.85 (48±9); 2.86 (38±6); 1.37 (120±15)
10	744	12.405	8.18 (100±5); 7.18 (24±4); 6.29 (7±3); 4.75 (8±3); 4.23 (78±5); 3.85 (22±4); 2.86 (27±5); 1.37 (49±7)
14	877	12.532	12.53 (100±3); 11.16 (11±2, 9±2); 8.30 (39±2); 7.72 (5±2); 7.31 (8±4); 6.30 (5±3); 6.00 (4±2); 5.00 (4±2); 4.80 (7±3); 4.23 (31±4); 3.85 (11±3); 2.86 (9±3); 1.37 (144±8)
16	989	12.640	11.27 (13±3); 9.4 (5±2); 8.52 (100±4); 7.45 (7±2); 6.60 (13±2); 4.62 (12±2); 4.23 (8±2); 3.85 (10±2); 2.75 (84±4); 1.37 (110±10)
19	1022	12.671	11.30 (24±3); 8.44 (100±4); 7.45 (30±4); 6.35 (6±2); 4.94 (14±3); 4.23 (85±5); 3.85 (29±4); 2.86 (25±3); 1.37 (94±10)
23	1166	12.809	12.81 (100±10); 11.44 (37±7)
24	1176	12.819	12.82 (100±10); 11.44 (21±4); 9.4 (12±4); 8.58 (66±5); 7.75 (13±6); 7.60 (13±6); 6.40 (37±7); 5.05 (38±7); 4.23 (70±20); 3.85 (12±5); 2.86 (25±8); 1.37 (94±15)
30	1321	12.958	12.96 (16±3); 11.59 (100±4); 1.37 (93±5)
34	1398	13.033	11.66 (14±2); 8.80 (35±4); 7.81 (100±8); 7.0 (6±3); 6.27 (11±3); 5.40 (19±4); 4.23 (42±5); 3.86 (99±8); 2.86 (27±5); 1.37 (160±10)
35	1419	13.053	11.68 (7±2); 10.1 (4±2); 8.93 (100±5); 4.60 (2±1); 4.23 (4±1); 3.85 (3±1); 2.75 (100±3); 1.37 (112±5)

a This resonance has been assigned energies from 869 keV to 877 keV in various studies. Using a thin target deliberately contaminated with F<sup>19</sup>, we find that the resonance is 1.4±0.4 keV above the strong in F<sup>19</sup>(p,αγ)O<sup>16</sup> reaction.

Notes	
14	Identification numbers assigned to $\gamma$ transitions to ground state in Mg <sup>24</sup> .
23	Data for these and other transitions are in Table II.
24	Detector at 55°.

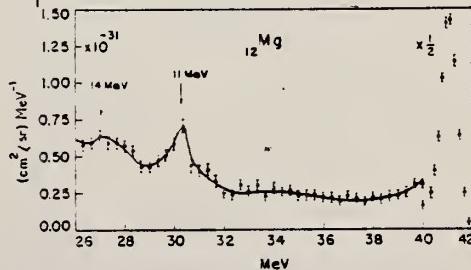
TABLE II. Absolute yields of the reaction  $\text{Na}^{23}(\text{p}, \gamma)\text{Mg}^{24}$ . The thick-target yields are those for an evaporated target of  $\text{Na}_2\text{SO}_4$ . The assumptions used in the calculation of  $(2J+1)\Gamma_\gamma$  are discussed in the text.

Resonance	Thick-target yield ( $\gamma$ 's/proton $\times 10^{11}$ )	$\omega_\gamma$ (ev)	$(2J+1)\Gamma_\gamma$ (ev)
6	5.4	0.21	1.9
7	16.6	0.70	5.6
9	3.7	0.16	1.3
10	4.6	0.20	1.6
14	12.1	0.58	5.1
16	5.9	0.29	2.4
19	45.2	2.3	20
23	5.3	0.28	4.4*
24	28.4	1.5	17
30	146	7.9	63
34	34.7	1.9	22
35	92.5	5.1	81*

\*  $\Gamma_\gamma$  assumed to be 0.5R.

Elem. Sym.	A	Z
Mg	24	12

Method						Ref. No.	
Linac (Stanford Mark II) - counter telescope						63Bal	BG
Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes	
$(e, e')$	41.5		eV			Inelastic electron scattering cross section at $180^\circ$ ( $\text{cm}^2/\text{sr} \times 10^{-32}$ )	
		11.0	21.0	1.76		4.4 $\pm$ 20%	
		$\sim 14$	15.8	0.83		1.5 $\pm$ 30%	
						The rad. widths correspond to transitions from the $0^+$ state to $1^+$ excited states.	
						*Mg has 3 isotopes. Most abundant $^{24}_{12}\text{Mg}$ (78.8%). Observed structure attributed to this isotope.	

Fig. 12. Spectrum of 41.5 MeV electrons scattered from a magnesium target at  $180^\circ$ .

Elem. Sym.	A	Z
Mg	24	12

Method	Ref. No.
Tandem accelerator; $\gamma$ -ray yield, spectra; NaI	63 Go 3 JHH

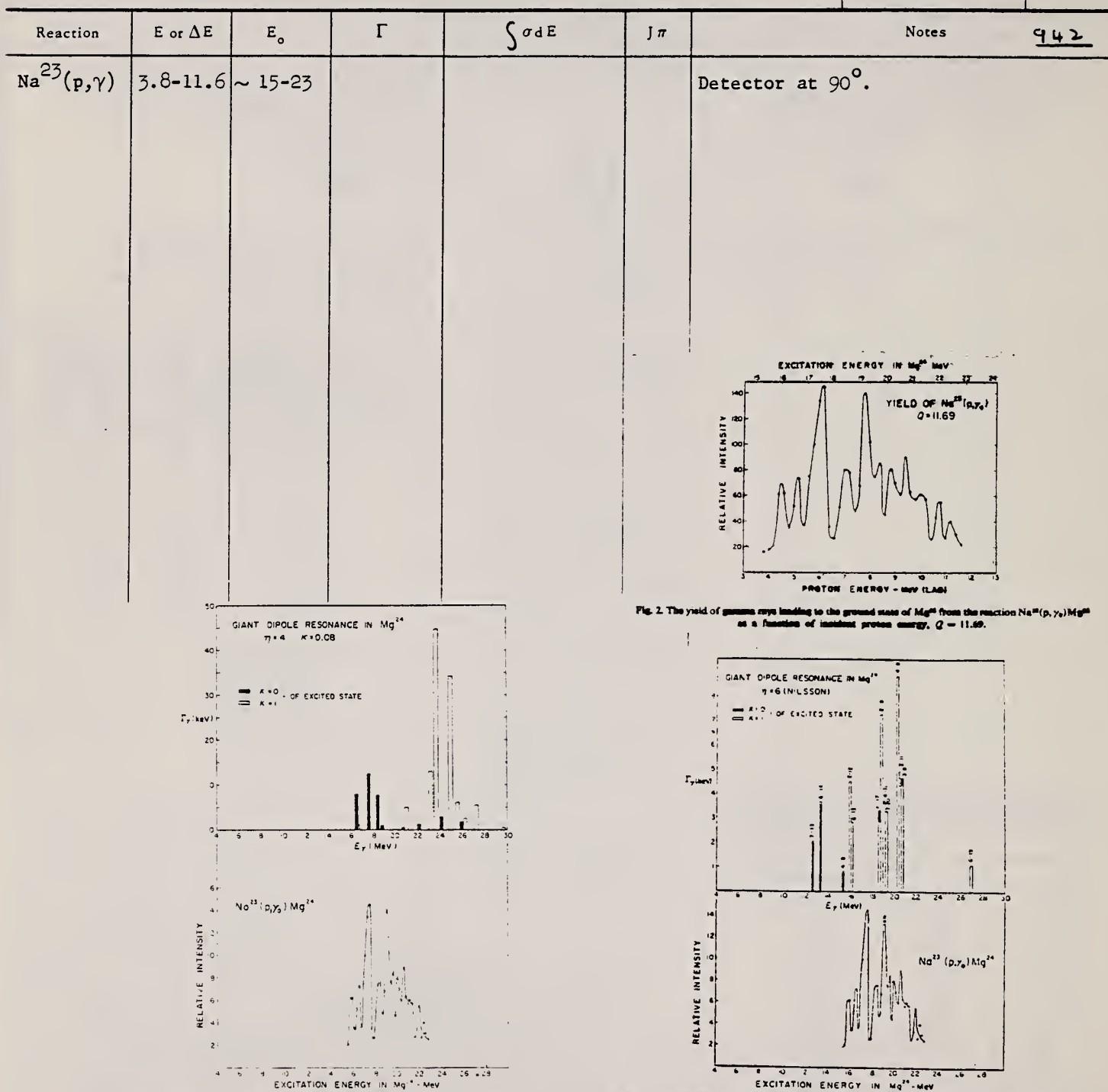


Fig. 3. Comparison between experimental results for the  $Na^{23}(p,\gamma)Mg^{24}$  reaction yield (lower half) and the predictions of Nilsson (upper half), where the Ferrell-Visscher exchange mixture correlations are included. See ref. [9].

[9] S. G. Nilsson, J. Sawicki and N. K. Glendenning. Nuclear Physics 33 (1962) 239

Elem. Sym.	A	Z
Mg	24	12

Method	emulsions					Ref. No.
Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$Mg^{24}(\gamma, C^{12*})$	Bremss. 70					Of 15 6- $\alpha$ events, at least two are consistent with $Mg^{24}(\gamma, C^{12*})C^{12*}$ .

Elem. Sym.	A	Z
Mg	24	12

Method  
synchrotron; foils; emulsions

Ref. No. 63Yal	BG
-------------------	----

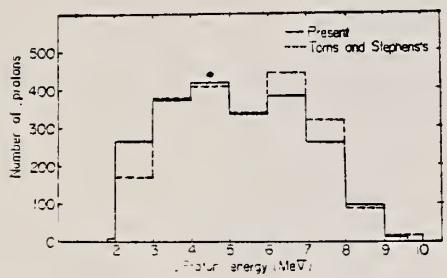
Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
( $\gamma$ , p)	bremss.: $E_{pmax} = 21.5$			( $4.1 \times 10^5$ protons/mole/roentgen; see Table I)		<p>Energy distributions of p's (Figs. 1, 2, 4)  Angular distributions fitted to <math>a + b \sin^2 \theta</math> (Table III, Fig. 3)</p> 

Fig. 1. Energy spectrum of photoprotons from Mg. (I) The solid line shows present and the dotted line is Toms and Stephens' result.

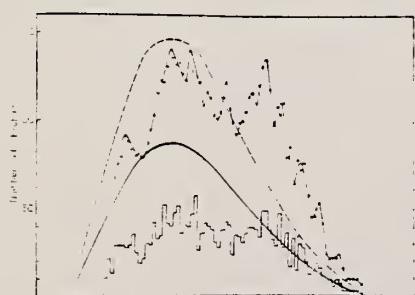


Fig. 2. Energy spectrum of photoprotons from Mg. (II) Histogram is shown in middle of 100 KeV and solid line through black circles shows the weighted spectrum averaged over the energy resolution of detection. The calculated distribution of the evaporative process is shown by the dotted curve and then multiplied by 0.6 is shown by the solid curve.

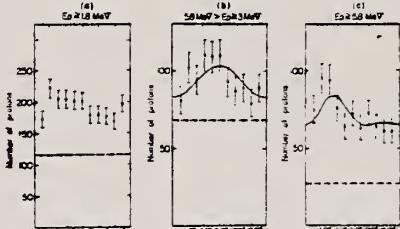


Fig. 3. Angular distributions of photoprotons from Mg. (a) all processes above 1.8 MeV, (b) processes of energy range from 3 to 5.8 MeV, (c) processes of energy range above 5.8 MeV.

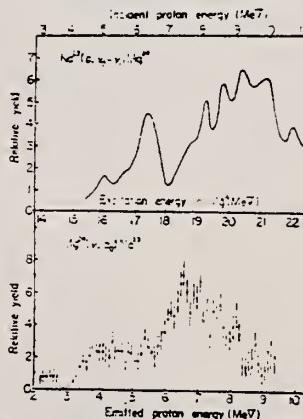


Fig. 4. The relative yield of Mg<sup>24</sup> ( $\gamma$ , p). Vertical lines represent the statistical error. The yield of Mg<sup>26</sup> ( $p, \gamma_1 + \gamma_2$ ) is taken from Gove et al.'s result, which is measured at 90° to the incident beam.

Table I. Photoprotton yield from magnesium.

Element	Yield Protons/mole: roentgen)	Brems- strahlung peak energy Mev)	Ref.
Mg	$7 \times 10^5$	23.5	8)
Mg	$4.1 \times 10^5$	21.5	present
Mg	$1.86 \times 10^5$	22.5	6)
Mg <sup>24</sup>	$1.74 \times 10^5$	24	6)

Table II. Abundance ratios and thresholds for ... p) reaction of the isotopes of magnesium.

	Abundance %	Threshold MeV
Mg <sup>24</sup>	78.8	11.7
Mg <sup>25</sup>	10.1	12.1
Mg <sup>26</sup>	11.1	14.3

Table III. The ratios of unisotropic part to isotropic part in the angular distribution of protons.  $b/a$  is the ratio for all process and  $b/a'$  for direct process.

Proton energy (Mev)	$b/a$	$b/a'$
$5.8 > E_p \geq 3$	$0.24 \pm 0.04$	1.33
$E_p \geq 5.8$	$0.09 \pm 0.02$	0.15

ELEM. SYM.	A	Z
Mg	24	12
REF. NO.	64 Bo 1	NVB

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	1-3	C	1 - 3	NAI-D		100

ABI

TABLE I  
 Cases of observed resonance fluorescence

Nucleus multipol.	State (MeV)	Spin	$\Gamma_0 \Gamma'$	$T(gw\Gamma_0^2/\Gamma'^2)^{-1}$ (sec.)	Mean lifetime $T$ BCW (sec)	Mean lifetime $T$ other (sec)	Ref.	$\Gamma_0/\Gamma_W$ BCW
Mg <sup>24</sup>	0.00	0 <sup>+</sup>						
E2	1.37	2 <sup>+</sup>	1	$4.1 \pm 1.3 \times 10^{-13}$	$13 \pm 4 \times 10^{-13}$	$16 \pm 4 \times 10^{-13}$	10)	50
Mg <sup>24</sup>	0.00	0 <sup>+</sup>						
E2*)	1.83	2 <sup>+</sup>	1	$12 \pm 5 \times 10^{-14}$	$37 \pm 15 \times 10^{-14}$	$70 \pm 30 \times 10^{-14}$	11)	22

ELEM. SYM.	A	Z
Mg	24	12

## METHOD

REF. NO.

Linac

64 Fi 2

JDM

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N	RLY	18-26	C	27-32	TDF-D	1-9	

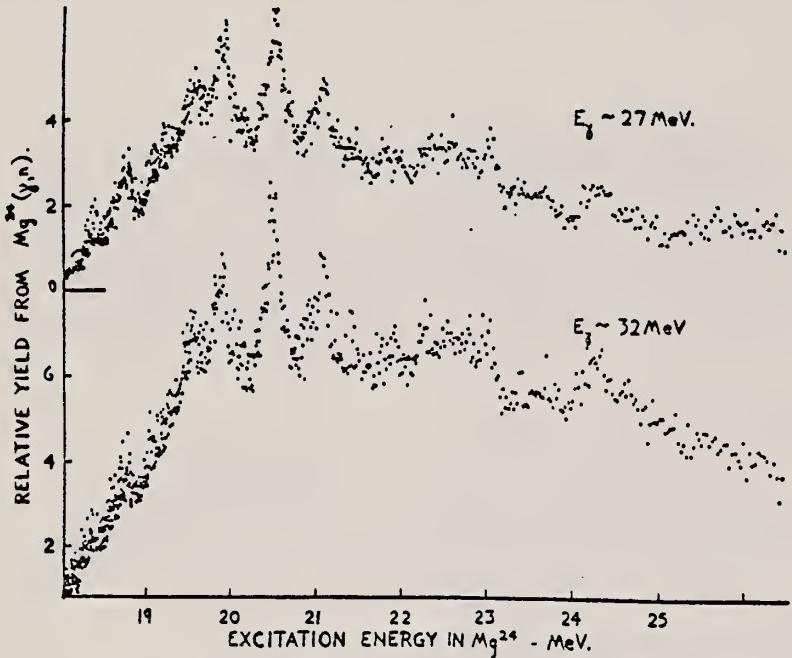


FIG. 1. — The observed relative yield of neutrons from  $\text{Mg}(\gamma, \text{n})$  for bremsstrahlung energies of 27 and 32 MeV (assuming ground state transitions).

METHOD

REF. NO.

100 MeV Linac;  $^{24}\text{Mg}(\gamma, ^{12}\text{B})^{12}\text{N}$

64 Sh 6

JDM

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, F	ABY	THR-100	C	100	ACT-I		4PI

$\gamma > 50 \text{ MeV-}\mu\text{b}$

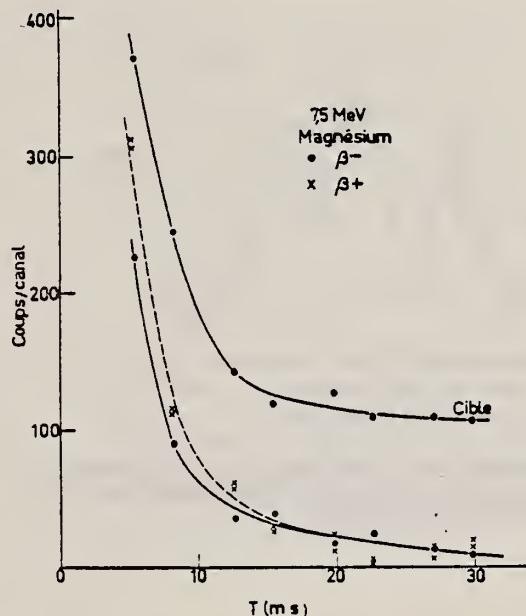


Fig. 1. — Comptages observés pendant des intervalles de 7 ms centrés à des temps  $T$  suivant l'impulsion de synchronisation de l'accélérateur.

REF. H. Artus, P. Brix, H. G. Clerc, F. Eigenbrod, A. Goldmann,  
F. Gudden, E. Spamer, P. Strehl, M. Stroetzel, O. Titze,  
and K. J. Wetzel  
Proc. Gatlinburg Conference, 314 (1966)

ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.	
66 Ar 2	hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,E/	LFT	9-22	D	52	MAG-D		141

945

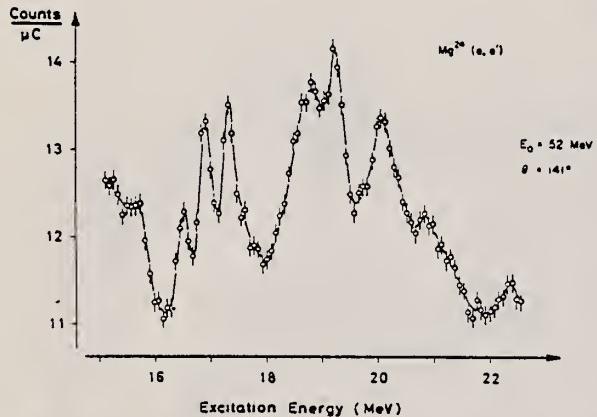


Fig. 1. Electron scattering from an isotopically enriched  $^{24}\text{Mg}$  target in the giant resonance region. Note the suppressed zero of the ordinate scale. The elastic peak has  $9 \cdot 10^3$  units of the ordinate scale.

TABLE I

Summary of Experimental Results<sup>a</sup>

Nuclide	$E_{\gamma}$ (MeV)	Type	$\Gamma_{\gamma}^0$ (eV)	$\Gamma_{\gamma}^0/\Gamma_w$	$R_{tr}$ (F)
$^6\text{Li}$	2.18	E2	$(3.9 \pm 0.5) \times 10^{-4}$	14.4	$3.77 \pm 0.48$
	3.56	M1	$8.9 \pm 0.4$	9.4	$2.96 \pm 0.11$
$^7\text{Li}$	$11.28 \pm 0.05$	(M1) or (M2)	$(1.3 \pm 0.4)/g^b$	$0.043/g$	—
			$(0.026 \pm 0.008)/g$	$2.6/g$	—
$^9\text{Be}$	$15.97 \pm 0.03$	M1	$(3.7 \pm 0.8)/g$	$0.043/g$	—
$^{11}\text{B}$	4.46	E2 and M1	$0.0173 \pm 0.0021$	8.2	$3.44 \pm 0.50$
			$0.64 \pm 0.08$	0.34	$2.60 \pm 0.35$
$^{12}\text{C}$	5.04	M1	$1.84 \pm 0.14$	0.69	$2.60 \pm 0.11$
	4.43	E2	$0.0122 \pm 0.0008$	5.30	$3.14 \pm 0.30$
$^{16}\text{O}$	6.92	E2	$0.100 \pm 0.015$	3.28	$3.82 \pm 0.46$
	11.52	E2	$0.52 \pm 0.13$	1.31	—
$^{24}\text{Mg}$	$9.85 \pm 0.04$	M1	$7.95 \pm 1.2$	0.38	$3.50 \pm 0.49$
	$9.97 \pm 0.03$				
	$10.35 \pm 0.03$	E2	$0.24 \pm 0.05$	0.58	$5.05 \pm 0.50$
	$10.70 \pm 0.03$	M1	$22.2 \pm 2.4$	0.86	$3.60 \pm 0.36$
	$10.93 \pm 0.04$	E2	$0.26 \pm 0.11$	0.50	—
$^{28}\text{Si}$	$4.97 \pm 0.02$	C0	$(2.0 \pm 0.5) \times 10^{-5}^c$	—	$6.90 \pm 1.20$
$^{40}\text{Ca}$	$6.89 \pm 0.05$	E2	$0.29 \pm 0.04$	2.85	$4.60 \pm 0.50$

<sup>a</sup>The Born approximation has been used except for  $^{16}\text{O}$  and  $^{40}\text{Ca}$ .

<sup>b</sup> $g = (2I_i + 1)/(2I_i + 1)$ .

<sup>c</sup> $\Gamma_{\gamma}^0$  equivalent to  $ME = (8.87 \pm 1.00) F^2$ .

ELEM. SYM.	A	Z
Mg	24	12

METHOD			REF. NO.	
			66 Is 1	EGF
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR
			TYPE RANGE	TYPE RANGE
G,P	ABX	THR-34	C 15-30	EMU-D 2-14
				DST



Fig.1. Energy distribution of photo-protons from magnesium irradiated with  $E_{\gamma\text{max}} = 23$  MeV bremsstrahlung.

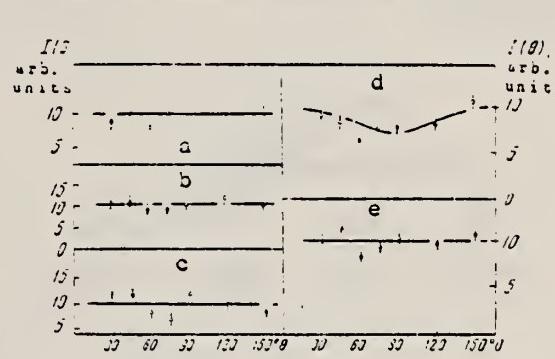


Fig.3. Angular distributions of photo-protons from magnesium irradiated with  $E_{\gamma\text{max}} = 23$  MeV bremsstrahlung. The different curves are for photoprotons with energies in the following ranges (in MeV): a) 3.8-4.5, b) 4.6-5.5, c) 5.6-6.6, d)  $\geq 6.7$ , e)  $\geq 1.9$ .

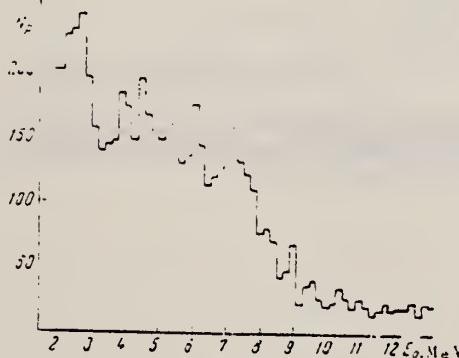


Fig.2. Energy distribution of photo-protons from magnesium irradiated with  $E_{\gamma\text{max}} = 34$  MeV bremsstrahlung.

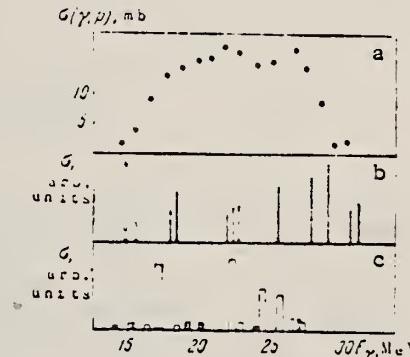


Fig.4. Photoproduction cross sections of magnesium: a - the present measurements; b - calculated cross sections of Ref. 3; c - calculated cross sections of Ref. 2.

ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.

66 Mi 2

egf

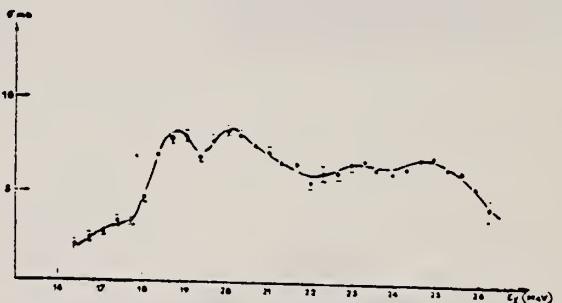
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N	ABX	16-27	D	16-27	BF <sub>3</sub> -I		4PI

334

## TABLEAU V

 $\sigma_{int}$  à 26 MeV en MeV.mb

	<sup>16</sup> O	<sup>40</sup> Ca	<sup>12</sup> C	Mg
$\gamma, n$	$41,5 \pm 4$	$73 \pm 7$	$29,4 \pm 3$	$58 \pm 6$

FIG. 4. —  $\sigma(\gamma, n)$  dans <sup>24</sup>Mg. Points expérimentaux de mai 1963. La courbe tient compte de la largeur finie de la raie de photons (400 keV).

METHOD

REF. NO.

66 Ti 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	LFT	7-15	D	51	MAG-D	36-51	DST

Angular distribution measured for  $q = 0.48, 0.41, 0.32 \text{ fm}^{-1}$ .

DST CONST Q

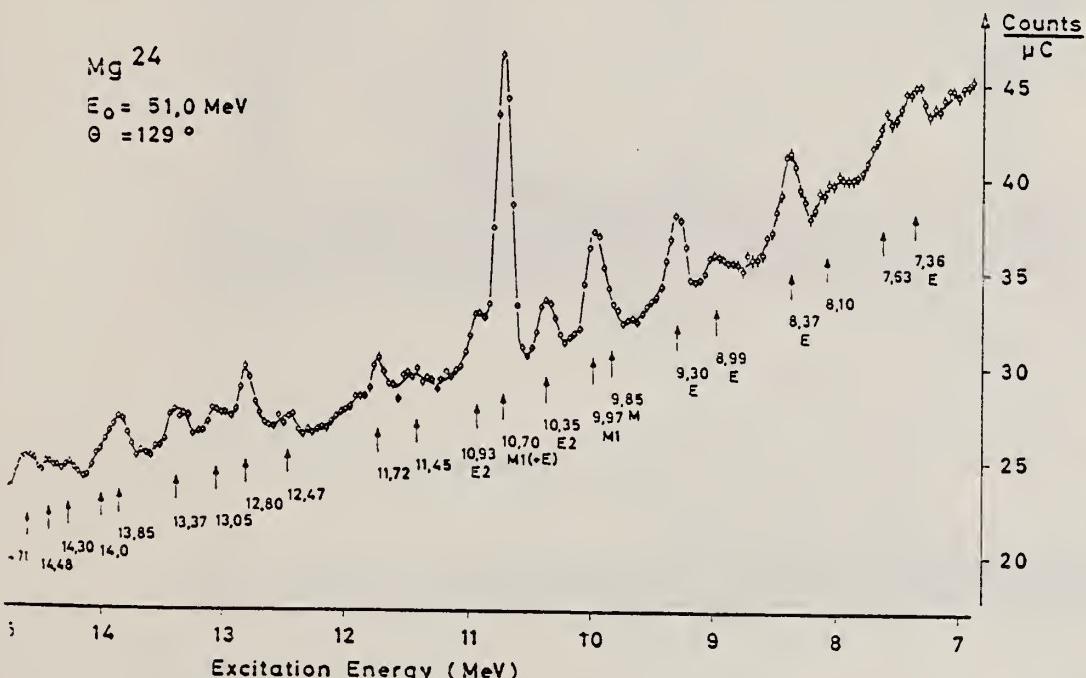


Fig. 1. Spectrum of inelastically scattered electrons from  $^{24}\text{Mg}$ . The effective target thickness was  $50 \text{ mg/cm}^2$ . The arrows indicate the measured excitation energies in MeV. The type of transition [electric (E) or magnetic (M)] is labeled. Note the suppressed zero of the ordinate scale. The elastic peak has a height of  $2.4 \times 10^4$  units of the ordinate scale.

$E_x$ (MeV)	$\Gamma_\gamma^0$ (eV)	$\Gamma_\gamma^0/\Gamma_W$	$R_{tr}$ (fm)
$9.85 \pm 0.04$	M1	$7.95 \pm 1.2$	$0.38$
$9.97 \pm 0.03$	{ M1 E2	$0.24 \pm 0.05$	$3.50 \pm 0.49$
$10.35 \pm 0.03$	E2	$0.24 \pm 0.05$	$0.58$
$10.70 \pm 0.03$	M1	$22.2 \pm 2.4$	$0.86$
$10.93 \pm 0.04$	E2	$0.26 \pm 0.11$	$3.60 \pm 0.36$
			—

\* Calculated with  $R_{tr}$  from  $10.35 \text{ MeV}$  transition.

Table 1. Results for  $^{24}\text{Mg}$ . The first two columns give excitation energies and multipolarities as determined from this work. Column 3 to 5 show the ground state radiation widths  $\Gamma_\gamma^0$ , the transition strengths in WEISSKOPF units  $\Gamma_W$  and the transition radii  $R_{tr}$ . The Bonn approximation has been used.

[ over ]

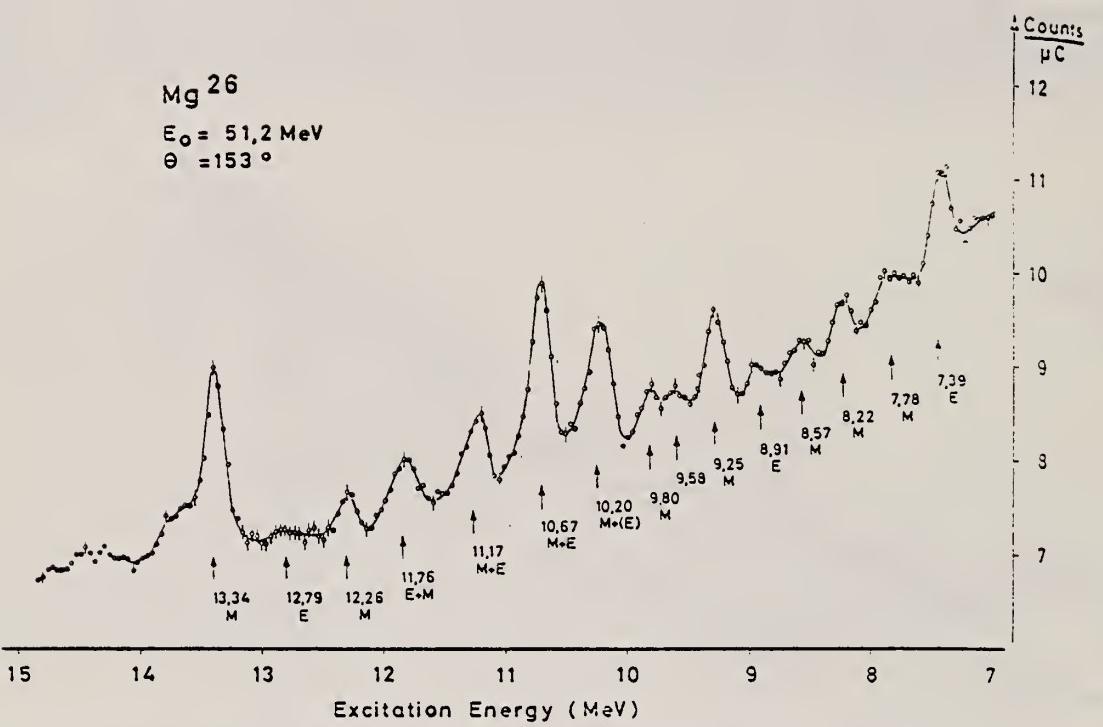


Fig. 2. Spectrum of inelastically scattered electrons from  $^{26}\text{Mg}$ . The effective target thickness was  $170 \text{ mg/cm}^2$ . The arrows indicate the measured excitation energies in MeV. The type of transition [electric (E) or magnetic (M)] is labeled. Note the suppressed zero of the ordinate scale. The elastic peak has a height of  $2.5 \times 10^3$  units of the ordinate scale.

METHOD

REF. NO.

67 Ku 2

HMG

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	9-11	D	9-11	NAI-D	9-11	135

Photons, defined in energy to about 1% with the aid of a bremsstrahlung monochromator, were scattered by isolated energy levels in C, Mg, and Si. Parameters for the six observed levels are:

Isotope	Energy (MeV)	$\Gamma_0^2/\Gamma$ (eV)	$\Gamma_0/\Gamma$	$B(M1)/(e\hbar/2M_p)^2$
C <sup>13</sup>	15.11	36	1	0.93
Mg <sup>24</sup>	10.66±0.02	14	0.8	1.21
Si <sup>23</sup>	11.42±0.02	23	1	1.33
Si <sup>29</sup>	12.33±0.03			
Mg <sup>24</sup>	9.92±0.03	3.0	0.5	0.49
Mg <sup>24</sup>	10.07±0.05	4.2		≥0.36

The 15.11-MeV level in C<sup>13</sup>, the 9.92- and 10.66-MeV levels in Mg<sup>24</sup>, and the 11.42-MeV level in Si<sup>29</sup> are  $T=1$ ,  $T_z=0$  analogs of low-lying 1+ states in the neighboring odd-odd nuclei. These levels exhaust most of the magnetic dipole transition strength of the respective nuclei, and therefore give information about the expectation value of l-s in the ground state.

ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.

67 Le 1 egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P,G	ABX	16-25	D	5-14	MGP-D	8-25	90

943

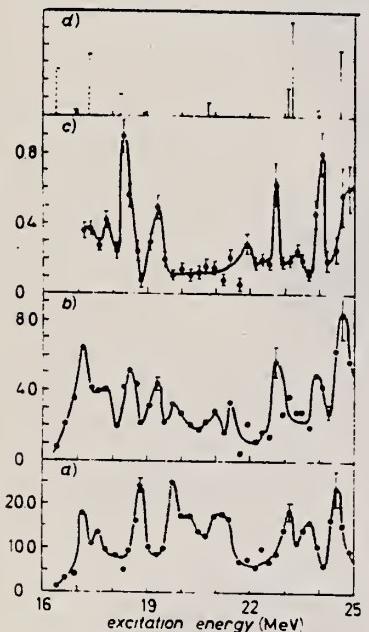


Fig. 2. - a) The 90° yield for the reaction  $^{22}\text{Na}(p, \gamma)^{24}\text{Mg}$  as a function of excitation energy in  $^{24}\text{Mg}$ . The ordinate unit is  $\mu\text{h}/\text{keV}$ . b) As a) for the reaction  $^{23}\text{Na}(p, \gamma)$ . c) The ratio of these two yields. d) The results of one of the calculations by NILSSON *et al.* (<sup>1</sup>), using a Fermi-Visscher interaction and considering ground-state correlations.

—  $K = 1$ , - - -  $K = 0$ .

METHOD				REF. NO.	
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE RANGE	TYPE RANGE	
E, E/	SPC	15-26	D 45-54	MAG-D	DST

944

Spectrometer resolution 145-180 keV.

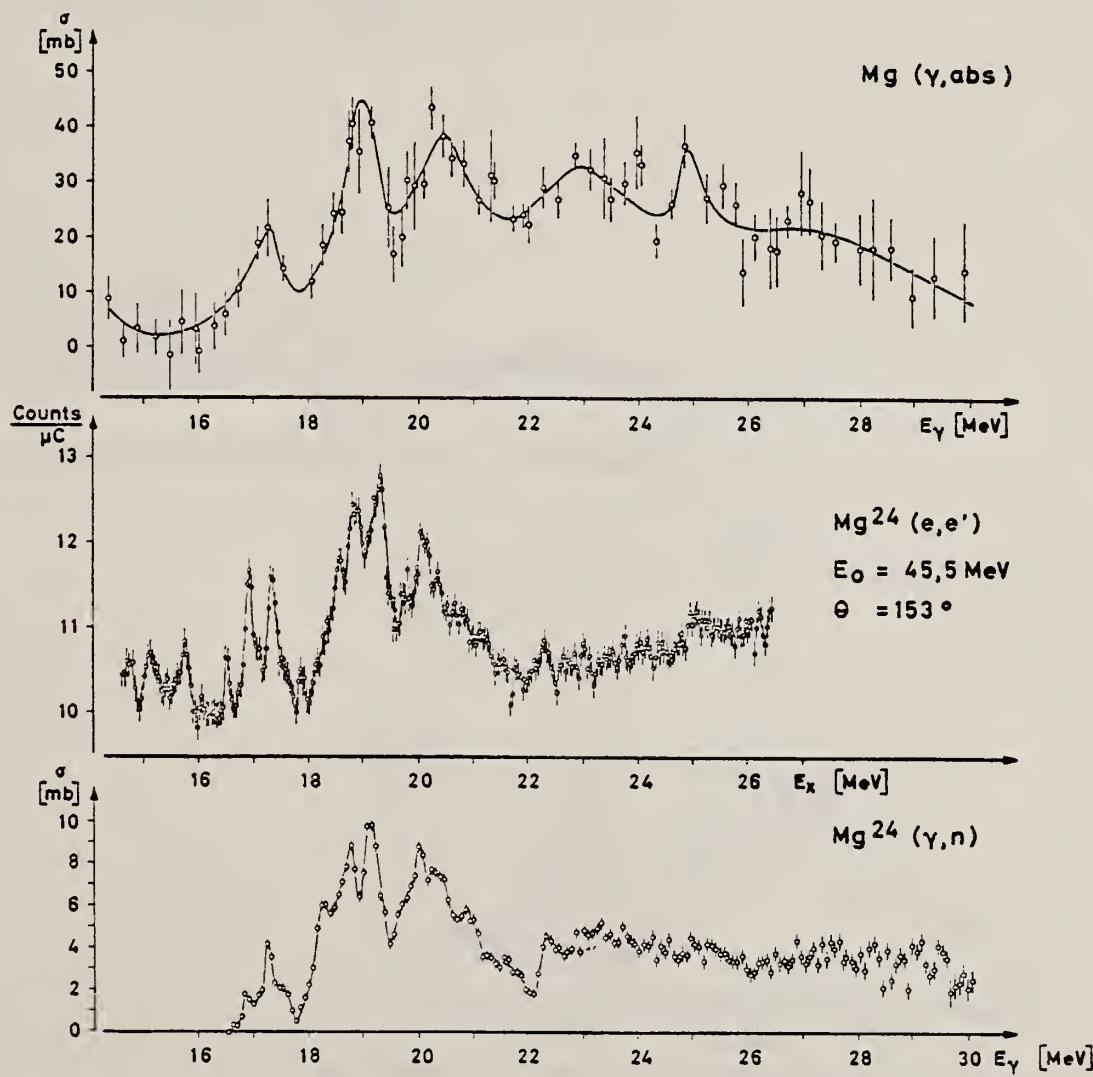


Fig. 1. Giant resonance of  $^{24}\text{Mg}$ . The upper part gives the photonuclear cross section for natural magnesium [2], the lower the photoneutron cross section of  $^{24}\text{Mg}$  [3]. The center shows a spectrum of inelastically scattered electrons. Note the suppressed zero of the ordinate scale. The effective target thickness was  $86 \text{ mg/cm}^2$ . The height of the elastic peak is  $8 \times 10^3$  units of the ordinate scale.  $E_x, E_\gamma$  are excitation energy and photon energy, respectively.



ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.

[Page 1 of 3] 68 Be 3

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
P, G	ABX	16-24	D	4-13	NAI-D	16-24	DST
	.						

798+

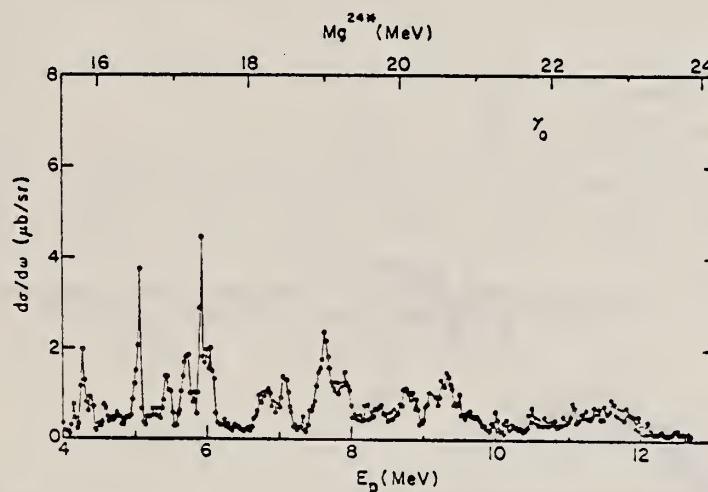


Fig. 2. Yield curve at 90° of the ground-state gamma ray from the  $^{23}\text{Na}(p,\gamma)$  reaction.

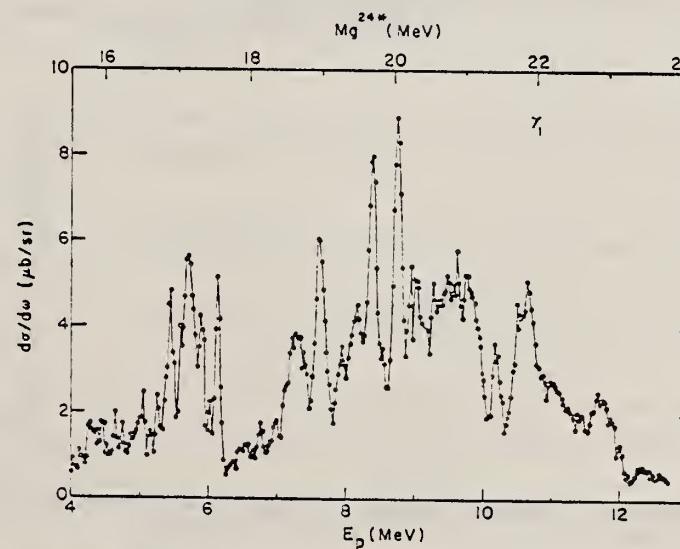


Fig. 3. Yield curve at 90° of the gamma ray to the 1.37 MeV first excited state in  $^{24}\text{Mg}$  from the  $^{23}\text{Na}(p,\gamma)$  reaction.

[over]

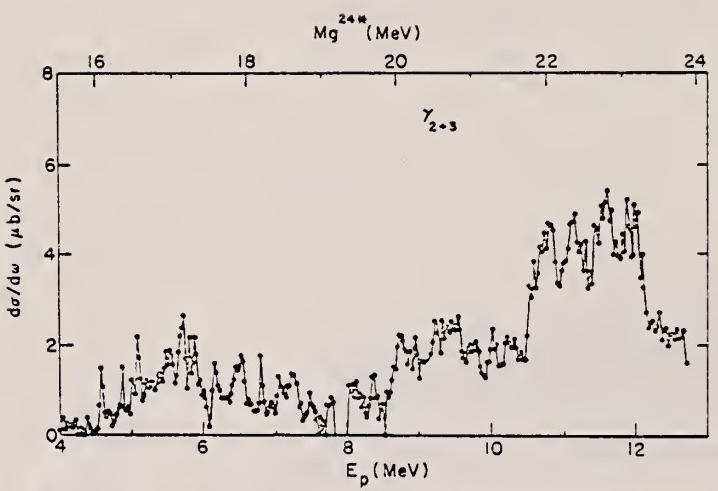


Fig. 4. Yield curve at 90° of the (unresolved) gamma rays feeding the doublet at 4.12 and 4.23 MeV in  $^{24}\text{Mg}$  from the  $^{23}\text{Na}(\text{p}, \gamma)$  reaction.

METHOD

REF. NO.

[Page 3 of 3] 68 Be 3

egf

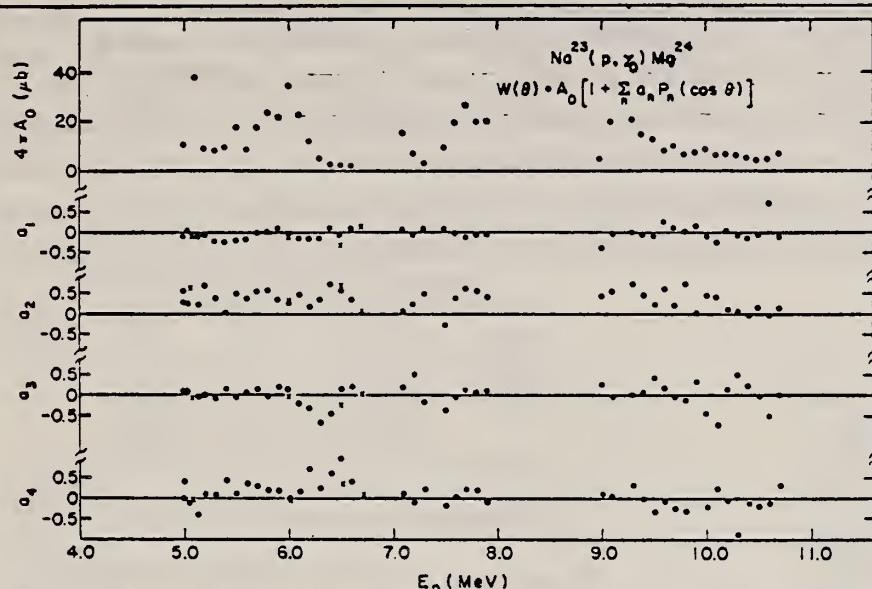


Fig. 10. Coefficients obtained in fitting series of Legendre polynomials to the angular distributions for  $^{23}\text{Na}(\text{p}, \gamma)^{24}\text{Mg}$ . The data were taken with 100 keV resolution.

DETECTOR		ANGLE
TYPE	RANGE	

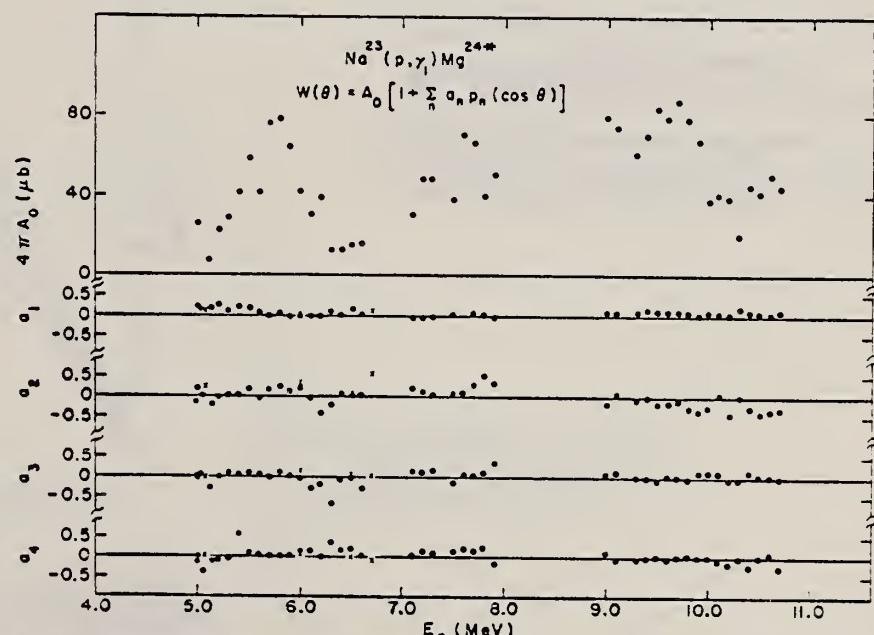


Fig. 11. Coefficients obtained in fitting series of Legendre polynomials to the angular distributions for  $^{23}\text{Na}(\text{p}, \gamma_1)^{24*}\text{Mg}$ . The data were taken with 100 keV resolution.

METHOD

REF. NO.

68 Co 1

HMG

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N	RLX	THR- 65	C	13-65	ACT-I		4PI

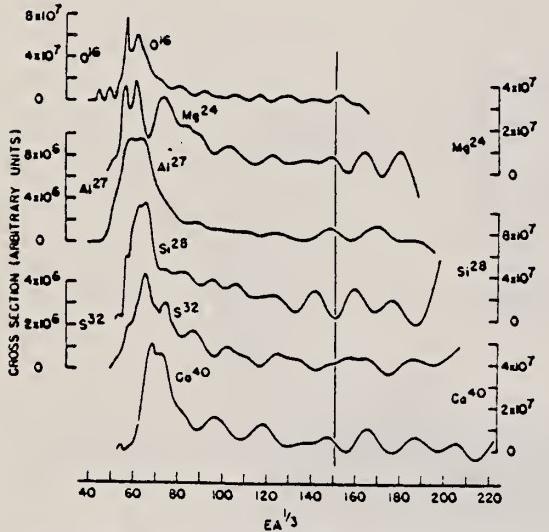


Fig. 1. Cross section for elements in the s-d shell as a function of  $EA^{1/3}$ . The vertical line is only an aid to the eye. Universal curves expected for the hydrodynamical model are not evident.

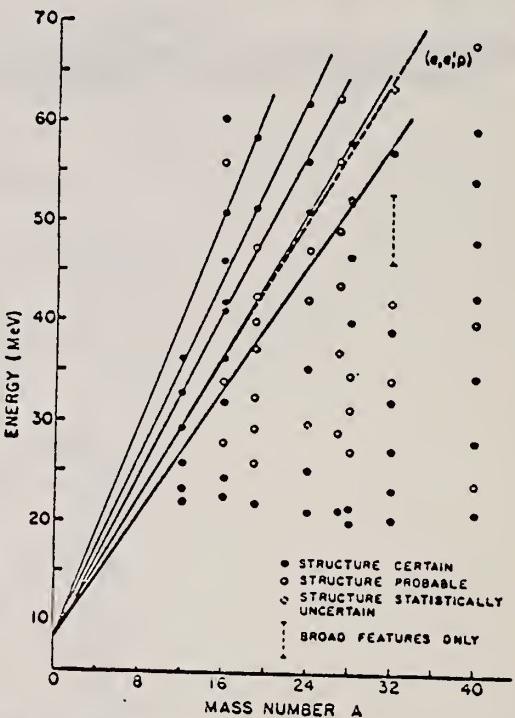


Fig. 2. A dependence of structure. A qualitative estimate for the statistical validity for structure is also indicated. The solid straight lines have the form  $mA + 8$  MeV while the dashed line represents the position of the 1s level as determined from  $(e,e'p)$  experiments.

METHOD

FOR REANALYSIS OF THIS DATA SEE: 70 Fa 1

REF. NO.

68 Fa 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	LFT	7-28	D	39,56	MAG-D	28-56	180

TABLE I. Values of transition widths and radii.

DETAILS 9.9; 10.7

Transition parameter	Energy (MeV)	Present work	Titze and Spamer*	Kuehne et al. <sup>b</sup>
$\Gamma$ (eV)	9.9±0.03	11.9±2.7	7.95±1.2	5.6±3.0 <sup>a</sup>
	10.70±0.03	18.9±3.7	22.2 ±2.4	17.0±4.0
$R(\Gamma)$	9.9±0.03	3.5±0.2	3.50±0.49	
	10.70±0.03	3.0±0.2	3.60±0.36	

\* Reference 6.

<sup>a</sup> Reference 5.

<sup>b</sup> Error not given by authors; it is estimated here from information given in Ref. 5.

H. W. Kuehne, P. Axel, and D. C. Sutton, Phys. Rev. 163, 1278 (1967).

O. Titze and E. Spamer, Z. Naturforsch. 21a, 1504 (1966).

M. Rosen, R. Raphael, and H. Uberall, Phys. Rev. 163, 927 (1967).

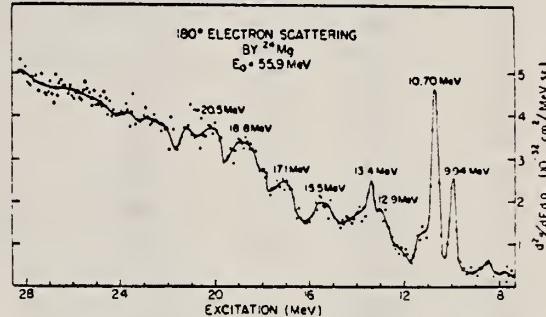


FIG. 1. Differential cross section for 180° electron scattering from  $^{24}\text{Mg}$  at  $E_0=55.9$  MeV covering the excitation energy range from about 7 to 28 MeV.

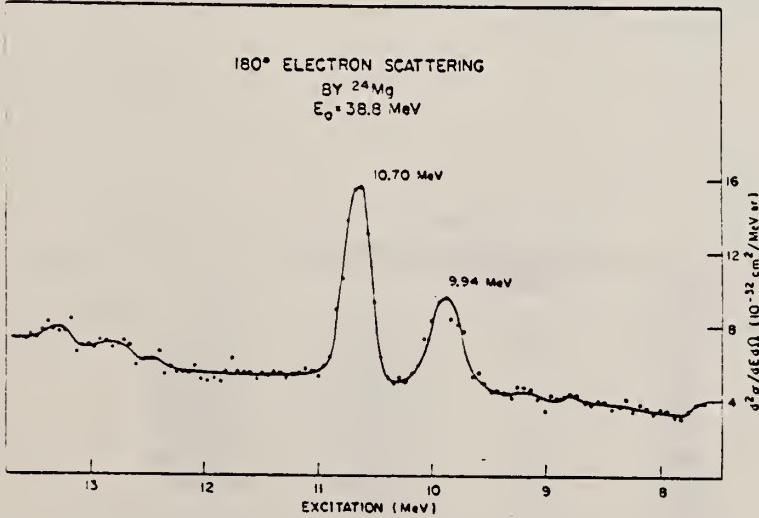


FIG. 2. Differential cross section for 180° electron scattering from  $^{24}\text{Mg}$  at  $E_0=38.8$  MeV covering the excitation energy range from 8 to 14 MeV.

METHOD

REF. NO.

68 Hi 1 EGF

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
A, G	RLX	11-14	D	3-6	NAI-D	7-16	DST

TABLE 1  
Resonances in  $^{20}\text{Ne}(\alpha, \gamma)^{24}\text{Mg}$  reaction

J-PI, G-WIDTH

$E_x$ (MeV)	$E_x$ (MeV) *	$J^\pi$	$\gamma_0$	$\gamma_1$	$\gamma_1 + \gamma_3$	$(2J+1)\Gamma_x\Gamma_\gamma/\Gamma$ (eV)
3.056	11.863	1-	1	0.7		2.4 c)
3.187	11.972	2+	0.3	1		0.7 c)
3.245	12.020	<0.3	1			2.0
3.289	12.057	<0.05	<0.2	1		$\leq 33^d)$
3.422	12.168	(2+, 4+)	<0.3	1	0.9	5.8
3.715	12.412	<0.2	<0.2	1( $\gamma_3$ )		20
3.792	12.476	2+	0.4	1		2.3
3.836	12.513	(2+, 4+)	<0.3	1	0.3	7.3
3.920	12.583	2+	1	0.1	0.1	0.9
3.997	12.647	<0.03	<0.2	1		12
4.109	12.740	2+	0.7	1	0.2	0.7
4.193	12.810	2+	1	0.4		1.8
4.483	13.052	<0.04	<0.1	1		25
4.528	13.089	2+	1	0.07	0.7	2.0
4.913	13.410	(1-, 2+)	0.09	1		2.9
(4.944) b)	(13.436)					
5.653	14.026	1-	0.6	1		12
5.720	14.082	<0.07	<0.3	1( $\gamma_3$ )		9.8
5.743 b)	14.101					
5.796	14.146	<0.07	<0.2	1( $\gamma_3$ )		12
6.017	14.330	2+, 3-, 4+	<0.07	0.36	1( $\gamma_3$ )	10
all $\pm 5$ keV					all $\pm 50$ %	

a) Calculated using  $Q = 9.317$  MeV, ref. <sup>22</sup>.

b) Energy uncertainty  $\pm 10$  keV.

c) Ref. <sup>14</sup>.

d) See subsect. 3.3.

TABLE 2  
Angular distribution coefficients

$E_x$ (MeV)	Transition	$A_2$	$A_4$
3.245	$\gamma_1$	$+0.07 \pm 0.10$	$+0.03 \pm 0.13$
3.422	$\gamma_1$	$+0.47 \pm 0.14$	$-0.30 \pm 0.18$
3.715	$\gamma_3$	$+0.47 \pm 0.04$	$-0.04 \pm 0.06$
3.836	$\gamma_1$	$+0.49 \pm 0.04$	$-0.42 \pm 0.06$
3.920	$\gamma_0$	$+0.42 \pm 0.30$	$-2.05 \pm 0.43$
4.109	$\gamma_1$	$+0.56 \pm 0.22$	$-0.42 \pm 0.28$
4.913	$\gamma_1$	$+0.31 \pm 0.13$	$-0.11 \pm 0.17$
5.653	$\gamma_0$	$-0.99 \pm 0.13$	
5.720	$\gamma_2$	$+0.38 \pm 0.09$	$-0.17 \pm 0.11$

ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.

68 Ok 2

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N	ABY	THR-20	C	20	ACT-I		4PI

ISOMERIC YIELD

TABLE I. THE PARTICULARS OF THE ( $\gamma, n$ ) REACTION PRODUCTS AND THE DATA OBTAINED WITH 20 MeV BREMSSTRAHLUNG

Parent (Natural abundance, %)	Residual	Half-life of product (sec)	Gamma-ray determined				Yield (mol <sup>-1</sup> ·R <sup>-1</sup> )
			Energy (MeV)	Branching ratio (%)	Photopeak activity (cpm/mg) <sup>a</sup>	Limit of detection ( $\mu$ g)	
<sup>24</sup> Mg(78.60)	<sup>23</sup> Mg	9.9	0.511	200	$2.04 \times 10^6$	0.49	$8.1 \times 10^4$
<sup>76</sup> Ge(7.67)	<sup>75m</sup> Ge	48	0.139	100	$6.37 \times 10^5$	1.6	$1.1 \times 10^4$
<sup>78</sup> Se(23.52)	<sup>77m</sup> Se	17	0.162	100	$1.82 \times 10^6$	0.55	$1.2 \times 10^4$
<sup>92</sup> Mo(15.86)	<sup>91m</sup> Mo	65	0.630	57	$2.22 \times 10^5$	4.5	$2.7 \times 10^4$
<sup>140</sup> Ce(88.48)	<sup>139m</sup> Ce	58	0.745	100	$1.06 \times 10^6$	0.95	$1.3 \times 10^4$
<sup>142</sup> Nd(27.13)	<sup>141m</sup> Nd	64	0.760	100	$3.19 \times 10^5$	3.1	$1.4 \times 10^4$
<sup>158</sup> Tb(100)	<sup>156m</sup> Tb	11	0.111	100	$2.56 \times 10^5$	3.8	$2.2 \times 10^4$

a) The value corrected at the end of one-minute irradiation with the dose rate of  $10^7$  R/min; Counting geometry is 20% with a 3"dia.  $\times$  3"NaI(Tl) detector.

ELEM. SYM.	A	Z
Mg	24	12
REF. NO.		
69 An 2		egf
CTOR		ANGLE
RANGE		
		4PI

## **METHOD**

**REF. NO.**

69 An 2

egf

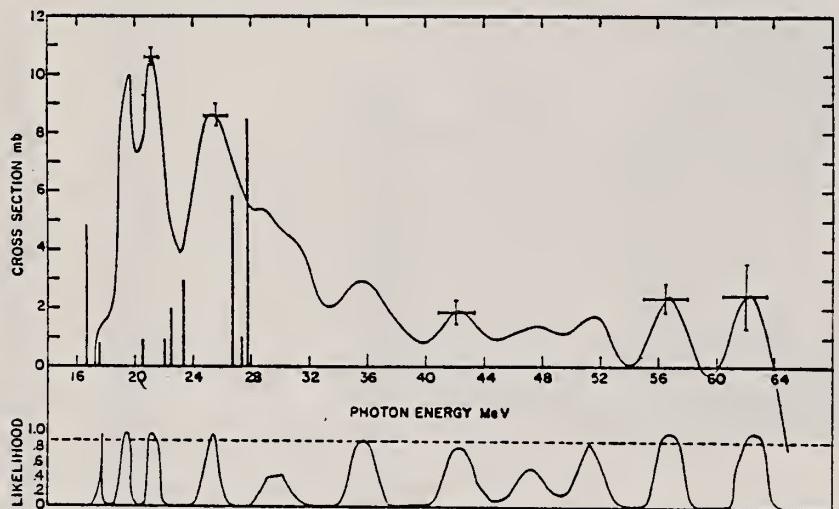


Fig. 2. The least structure cross-section solution for  $\sigma_{\text{in}} + 0.6 \sigma_{\text{in}}$ . The coefficient for  $\sigma_{\text{in}}$  results because the experimental timing cycle used was less efficient for accumulating yield data for  $^{22}\text{Mg}$  ( $\tau_1 = 3.9$  sec) than for  $^{22}\text{Mg}$  ( $\tau_1 = 11.2$  sec). A likelihood estimate for the statistical significance of peaks is also shown. Peaks with likelihood of 0.9 are considered significant. The vertical lines represent  $\Gamma_\gamma$  of the strongest transitions of a calculation by Bassichis and Scheck <sup>10</sup>.

<sup>23</sup> W.H.Bassichis and F.Scheck, Phys.Lett.19 (1965)509.

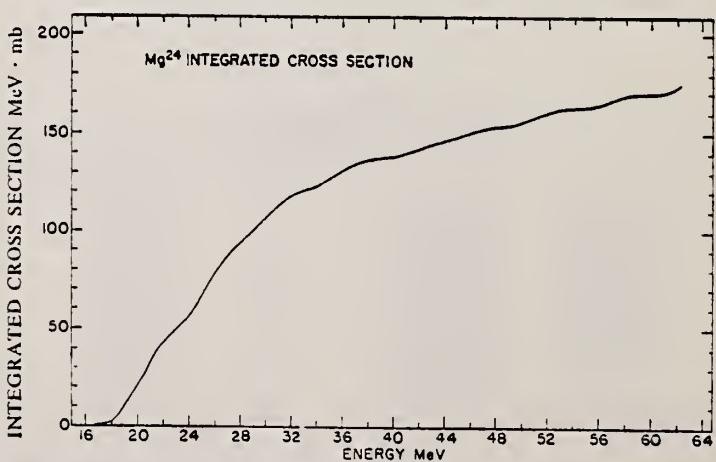


Fig. 3. The integrated cross section  $\Sigma(E) = \int_0^E (\sigma_{\text{in}} + 0.6 \sigma_{\text{sa}}) dE$  shown as a function of energy.

METHOD

REF. NO.

69 Ti 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	FMF	1-12	D	37-51	MAG-D	26-51	DST

TABULAR DATA

Tabelle 2. Zusammenstellung der Ergebnisse. Spalten 1–6 zeigen die Ergebnisse dieser Arbeit, Spalten 7–9 enthalten Vergleichswerte anderer Autoren. Hier sind die Werte  $E_x$ ,  $I^*$  Ref.<sup>1</sup> entnommen (ME: Matrixelement für  $E_0$ , BA: ausgewertet in Bornscher Näherung aus  $\sigma$ ,  $G = \Gamma_\gamma^0 / \Gamma_\omega$ )

$E_x$ [MeV]	$I^*$	$B(\Lambda_0)$ [fm <sup>-2</sup> ]	$\Gamma_\gamma^0$ [eV]	$R_{tr}$ [fm]	G	Vergleichswerte		
						$E_x$	$I^*$	G
1,366 (10)	2 <sup>+</sup>	455 (12)	3,49 (36) 10 <sup>-4</sup>	4,37 (35)	21,7 (25)	1,36857 (4)	2 <sup>+</sup>	viele, Mittelwert 25,9 ± 2,5 nach <sup>33</sup>
4,228 (10)	2 <sup>+</sup>	24,1 (20)	5,26 (92) 10 <sup>-3</sup>	4,12 (66)	1,15 (20)	4,233 (7)	2 <sup>+</sup>	> 14,7 <sup>35</sup> , 1,10 (20) <sup>33</sup> , 2,29 (46) <sup>7</sup> , (1,66) <sup>41</sup>
6,436 (15)	0 <sup>+</sup> (2 <sup>+</sup> )	6,23 (62) ME	—	5,66 (85)	—	6,436 (16)	0 <sup>+</sup>	
7,355 (20)	2 <sup>+</sup>	8,01 (79)	2,78 (58) 10 <sup>-2</sup>	4,60 (75)	0,38 (8)	7,349 (8)	2 <sup>+</sup>	1,30 (17) <sup>5</sup> , 3,9 <sup>6</sup> , 0,73 <sup>41</sup>
7,600 (21)	3 <sup>-</sup>	1,60 (31) 10 <sup>3</sup> BA	1,26 (43) 10 <sup>-4</sup>	5,2 (12)	6,5 (22)	7,620 (10)	3 <sup>-</sup>	4,96 <sup>5</sup> , 2,34 <sup>4</sup>
8,375 (18)	3 <sup>-</sup>	2,60 (22) 10 <sup>3</sup> BA	4,04 (67) 10 <sup>-4</sup>	4,12 (76)	10,5 (17)	8,357 (10)	(3 <sup>-</sup> ) <sup>4</sup>	2,60 <sup>5</sup> , 1,33 <sup>6</sup> , 2,9 <sup>4</sup> , 4,17 <sup>41</sup>
8,995 (21)	2 <sup>+</sup>	3,57 (38)	3,39 (78) 10 <sup>-2</sup>	4,22 (84)	0,17 (4)	9,004 (12)	2 <sup>+</sup> 2	
9,304 (19)	2 <sup>+(0<sup>+</sup>)</sup>	11,22 (91)	0,126 (23)	4,34 (64)	0,534 (97)	9,282 (12)		
9,846 (20)	1 <sup>+</sup>	3,14 (27) 10 <sup>-3</sup>	1,05 (26)	3,30 (60)	0,052 (13)	9,826 (12)		
9,972 (17)	1 <sup>+</sup>	1,300 (44) 10 <sup>-2</sup>	4,50 (73)	3,05 (44)	0,216 (35)	9,984 (16)	(1 <sup>+</sup> )	0,269 (48) <sup>14</sup> , 0,9 <sup>8</sup> , 0,57 (13) <sup>15</sup>
10,363 (19)	2 <sup>+(0<sup>+</sup>)</sup>	7,56 (61)	0,146 (31)	4,31 (86)	0,360 (76)	10,353 (20)		
10,716 (18)	(0 <sup>+</sup> )	3,79 (65) ME	—	(5,66)	—	10,683 (5)	0 <sup>+</sup> 3	3,8 (+12) <sup>8</sup> , 4,8 (+16) <sup>9</sup> , 5,3 (17) <sup>10</sup> , 0,90 (18) <sup>11</sup> , 0,66 (10) <sup>14</sup> , 0,73 (14) <sup>15</sup>
	1 <sup>+</sup>	3,71 (16)	15,9 (24)	3,22 (47)	0,616 (93)	10,737 (9)	(1 <sup>+</sup> )	
10,939 (20)	2 <sup>+</sup>	7,28 (10)	0,184 (58)	4,7 (10)	0,34 (11)	10,924 (5)	2 <sup>+</sup> 3	> 0,37 <sup>3</sup>
11,474 (30)	(2 <sup>+</sup> )	5,33 (38)	0,177 (44)	(4,30)	0,26 (7)	11,459 (5)	2 <sup>+</sup> 3	> 0,13 <sup>3</sup>
						11,460 (5)	0 <sup>+</sup>	

[over]

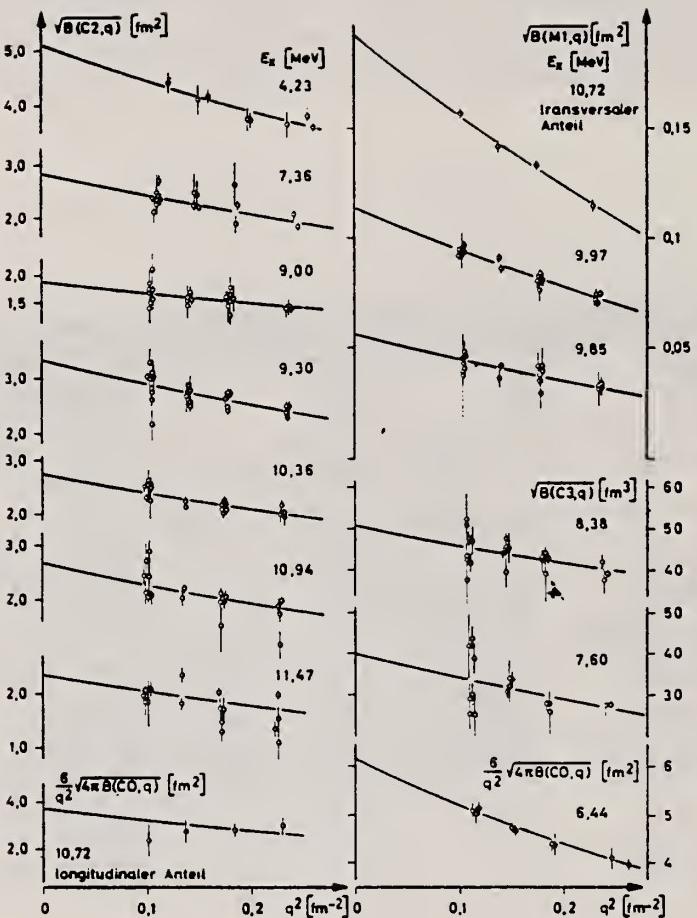


Fig. 2. Zusammenstellung der aus den korrigierten Wirkungsquerschnitten berechneten  $B(X \lambda, q)$  Werte als Funktion von  $q^2$ . Für C3-Ubergänge sind die unkorrigierten Werte angegeben, berechnet aus  $\sigma'$  (s. Gl. (14))

ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.

70 Fa 1

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	LFT	9-14	D	39,56	MAG-D		180

No new data-analysis of data found in 68 Fa 1.

REANALYSIS OF 68FA1

The data of an earlier paper presenting the results of 180° electron scattering from  $^{24}\text{Mg}$  have been re-examined using more refined data-treatment techniques. Present results favor an assignment of  $2^-$  for  $T=1$  states at 12.91 and 13.37 MeV with estimates for radiation widths  $\Gamma_0$  of 0.11 and 0.13 eV, respectively. Revised transition widths for the  $1^+$ ,  $T=1$  states at 9.94 and 10.70 MeV are found to be 7.6 and 17.6 eV, respectively, in better agreement with results of other workers.

TABLE I. Values of differential cross sections, spin and parity, transition radii, and radiation widths for energy levels excited in  $^{24}\text{Mg}$ . Transition radii and radiation widths have been corrected to the distorted-wave theory.

Level energy (MeV)	$(d\sigma/d\Omega)_{10}$ ( $10^{-24} \text{ cm}^2/\text{sr}$ )	$(d\sigma/d\Omega)_{20}$ ( $10^{-24} \text{ cm}^2/\text{sr}$ )	$J^\pi$	$R_M$ (fm)	$\Gamma_0$ (eV)
9.94 ± 0.03	104 ± 5	202 ± 15	$1^+$	$2.94_{-0.10}^{+0.18}$	$7.6_{-1.6}^{+1.6}$
10.70 ± 0.03	194 ± 7	372 ± 21	$1^+$	$2.94_{-0.11}^{+0.18}$	$17.6_{-2.5}^{+3.5}$
12.91 ± 0.06	76 ± 18	58 ± 33	$(2^-)$	$3.9_{-0.8}^{+1.4}$	$0.11_{-0.08}^{+0.14}$
13.37 ± 0.05	95 ± 18	63 ± 38	$(2^-)$	$3.5_{-0.8}^{+1.4}$	$0.13_{-0.08}^{+0.18}$



METHOD

REF. NO.

70 Go 3

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	ABX	15-26	D	45-55	MAG-D		DST

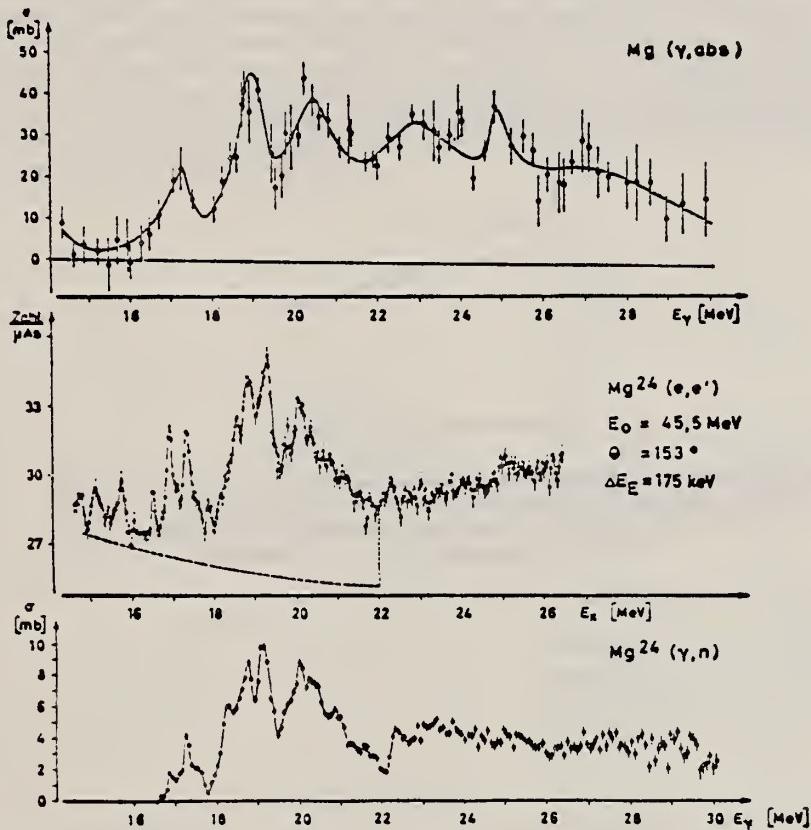


Fig. 1. Riesenresonanz von  $^{24}\text{Mg}$ . Oben: Absorptionswirkungsquerschnitt nach Dolbolkin et al.<sup>3</sup>, unten:  $\sigma(\gamma, n)$  nach Fultz et al.<sup>29</sup>. Mitte: Spektrum unelastisch gestreuter Elektronen. Der Strahlenschwanz wurde *nicht* subtrahiert, der Nullpunkt stark unterdrückt.  $E_x$  und  $E_\gamma$  sind Anregungs- bzw. Photonenenergien. Der zur Flächenbestimmung angenommene Untergrund und die Integrationsgrenzen sind gestrichelt eingezeichnet. Die Fläche der elastischen Linie ist  $A_g = 5.0 \cdot 10^3 \text{ MeV}/\mu\text{As}$

[over]

Tabelle 2. Ergebnisse an  $^{24}\text{Mg}$ . Bei allen Werten ist  $A_E = 5,0 \cdot 10^3 \text{ MeV}/\mu\text{As}$ . Die Flächen  $A_I$  wurden von 16,0 bis 22,0 MeV integriert. Bei der Auswertung wurden die im Text erwähnten Strahlungskorrekturen<sup>22,23</sup> nur auf der elastischen Fläche angebracht ( $K_I = 1,0$  in Gl. (2)). Die getrennte Auswertung der Bereiche von  $E_x = 16,0$  bis 18,0 MeV und von  $E_x = 18,0$  bis 22,0 MeV liefert mit den obigen Daten konsistente Ergebnisse

$E_0 [\text{MeV}]$	$\Theta [\text{Grad}]$	$q^2 [\text{fm}^{-2}]^a$	$A_I \left[ \frac{\text{MeV}}{\mu\text{As}} \right]$	$G [10^{-6}]^b$	$B(C1, q) [\text{fm}^2]$
54,5	129	0,17	24,5	4,53	1,01
50,4	153	0,16	48,0	2,45	0,95
15,3	153	0,12	26,5	2,41	1,05

<sup>a</sup> bei  $E_x = 19,7 \text{ MeV}$ .    <sup>b</sup>  $G = (d\sigma/d\Omega)_I (k_I^2/V_T)$ .

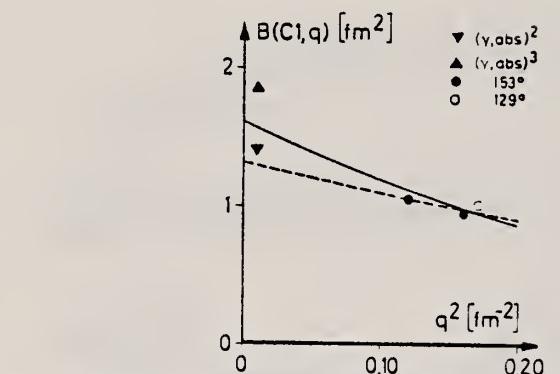


Fig. 2. Reduzierte Matrixelemente für den Bereich von 16,0 bis 22,0 MeV in  $^{24}\text{Mg}$ . Die Photonenwerte ( $\Delta$  entspricht 145 MeV mb,  $\nabla$  entspricht 110 MeV mb) wurden aus<sup>3,2</sup> berechnet. Die Kurven zeigen die Extrapolation zum Photonenpunkt für  $R_{tr} = 1,3 R_m$  (ausgezogen) bzw.  $R_{tr} = R_m$  (gestrichelt)

REF. V.M. Khvastunov, N.G. Afanas'ev, V.D. Afanas'ev, E.V. Bondarenko,  
 I.S. Gul'karov, G.A. Savitskii, and N.G. Shevchenko  
 Yad. Fiz. 12, 9 (1970)  
 Sov. J. Nucl. Phys. 12, 5 (1971)

ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.

70 Kh 1

hm<sup>g</sup>

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	FMF	1	D	225	MAG-D		DST
		(1.37)					

1 = 1.37

Elastic and inelastic scattering of 225-MeV electrons by the isotopes Mg<sup>24</sup> and Mg<sup>26</sup> have been measured. Analysis of the data was carried out in the Born approximation. From analysis of the elastic scattering for a uniform-Gaussian charge-distribution model it is found that addition of two neutrons to the Mg<sup>24</sup> nucleus leads to an increase in the parameter R by  $0.03 \pm 0.02$  fm and a decrease in g by  $0.07 \pm 0.04$  fm, which corresponds to a decrease in the mean-square radius of the Mg<sup>26</sup> nucleus by  $(1.6 \pm 1.3)\%$  in comparison with Mg<sup>24</sup>. Analysis of the inelastic scattering with excitation of the first 2<sup>+</sup> level shows that the internal quadrupole moments of the nuclei Mg<sup>24</sup> and Mg<sup>26</sup> are identical within experimental error.

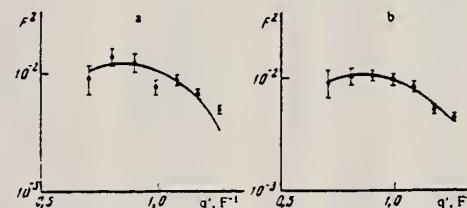


FIG. 3. Form factors for inelastic scattering with excitation of the first 2<sup>+</sup> levels, 1.37 MeV in Mg<sup>24</sup> (a) and 1.81 MeV in Mg<sup>26</sup> (b). The solid lines are theoretical curves calculated with Eq. (3).

#### Characteristics of the first 2<sup>+</sup> levels of the nuclei Mg<sup>24</sup> and Mg<sup>26</sup>

Nucleus	Level energy, MeV	$\beta_2(0^+, 2^+)$	$B(E2\uparrow)$ , $e^2 F^2$	$\tau, 10^{-13}$ sec	$g$	$Q_0, F^2$
Mg <sup>24</sup>	1.37	$0.31 \pm 0.02$	$442 \pm 43$	$20.5 \pm 2.4$	$20.1 \pm 2.1$	$04 \pm 4$
Mg <sup>26</sup>	1.81	$0.25 \pm 0.01$	$349 \pm 30$	$6.04 \pm 0.52$	$15.1 \pm 1.3$	$59 \pm 3$

ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.  
70 St 2  
egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR		ANGLE
			TYPE	RANGE	TYPE	
E, E/	ABX	6 (6.44)	D	31-59	MAG-D	DST

Tabelle 3. Experimentelle Parameter und Meßwerte.  $E_0$ ,  $\theta$  Primärenergie, Streuwinkel im Laborsystem.  $q$  unelastischer Impulsübertrag.  $\sigma/\sigma_E$  gemessenes Verhältnis von unelastischem zu elastischen differentiellen Wirkungsquerschnitt; in Klammer ist der statistische Fehler in % angegeben.  $d\sigma/d\Omega$  unelastischer differentieller Wirkungsquerschnitt; wegen der Fehlerangaben vgl. Text. Die Meßwerte für Si und S sind als Ergebnisse für  $^{28}\text{Si}$  und  $^{32}\text{S}$  aufzufassen (vgl. Text)

	$E_0$ (MeV)	$\theta$ (°)	$q^2$ (fm $^{-2}$ )	$\sigma/\sigma_E$ (10 $^{-4}$ )	$d\sigma/d\Omega$ (10 $^{-33}$ cm $^2$ /ster.)
$^{12}\text{C}$ 7,65 MeV	59,58	117,04	0,231	14,90 (0,6)	$24,69 \pm 1,60$
	56,94	129,02	0,231	13,79 (1,0)	$13,68 \pm 0,96$
	54,12	141,11	0,229	14,98 (0,7)	$8,15 \pm 0,55$
	52,75	153,15	0,231	15,24 (1,0)	$6,62 \pm 0,47$
	51,90	165,05	0,231	15,78 (1,8)	$1,16 \pm 0,09$
	51,18	104,98	0,145	5,80 (0,7)	$28,80 \pm 1,69$
	47,90	117,04	0,145	5,51 (0,7)	$17,19 \pm 1,01$
	45,48	129,02	0,145	5,97 (1,2)	$11,14 \pm 0,71$
	43,57	141,11	0,143	5,95 (1,1)	$6,09 \pm 0,38$
	42,54	153,15	0,145	5,82 (1,4)	$2,67 \pm 0,18$
	37,51	104,98	0,074	1,41 (1,4)	$15,38 \pm 1,07$
	35,08	117,04	0,073	1,33 (1,6)	$9,14 \pm 0,57$
	33,39	129,02	0,073	1,44 (1,7)	$5,89 \pm 0,37$
	32,04	141,11	0,073	1,39 (2,0)	$3,11 \pm 0,21$
	31,36	153,15	0,073	1,39 (3,2)	$1,39 \pm 0,11$
$^{24}\text{Mg}$ 6,44 MeV	59,01	116,94	0,232	5,53 (2,2)	$28,28 \pm 2,24$
	55,81	129,03	0,231	5,41 (1,5)	$16,65 \pm 1,20$
	53,64	140,95	0,231	5,65 (1,6)	$9,51 \pm 0,70$
	52,14	153,00	0,231	5,17 (2,1)	$3,95 \pm 0,32$
	50,85	104,96	0,074	0,59 (2,6)	$25,08 \pm 1,78$
	44,59	116,94	0,074	0,56 (3,2)	$15,09 \pm 1,16$
	32,87	129,03	0,074	0,58 (2,8)	$9,37 \pm 0,68$
	31,72	140,95	0,074	0,58 (3,1)	$5,10 \pm 0,39$
	30,86	153,00	0,074	0,68 (5,5)	$2,69 \pm 0,27$
$^{28}\text{Si}$ 4,98 MeV	58,38	116,94	0,232	5,61 (1,9)	$38,70 \pm 2,68$
	55,12	129,03	0,231	5,27 (0,9)	$21,98 \pm 1,34$
	52,87	141,11	0,231	5,58 (1,3)	$12,72 \pm 0,81$
	51,28	153,00	0,230	5,69 (1,9)	$6,00 \pm 0,42$
	49,93	104,96	0,145	2,05 (1,6)	$49,60 \pm 3,13$
	49,97	104,96	0,146	2,10 (1,4)	$50,68 \pm 3,09$
	46,77	116,94	0,146	2,23 (2,2)	$33,90 \pm 2,31$
	44,28	129,03	0,146	2,14 (2,0)	$19,48 \pm 1,29$
	42,44	141,11	0,146	2,20 (1,7)	$10,98 \pm 0,70$
	41,23	153,00	0,145	2,45 (2,1)	$5,64 \pm 0,38$
	41,37	153,00	0,146	2,48 (2,5)	$5,67 \pm 0,40$
	36,28	104,96	0,074	0,53 (4,5)	$32,51 \pm 2,90$
	36,26	104,96	0,074	0,56 (4,0)	$34,35 \pm 2,89$
	33,98	116,94	0,074	0,55 (4,3)	$21,28 \pm 1,83$
	32,17	129,03	0,074	0,52 (4,0)	$11,98 \pm 1,00$
	30,87	141,11	0,073	0,59 (5,3)	$7,54 \pm 0,73$
	29,96	153,00	0,073	0,66 (5,7)	$3,89 \pm 0,39$
	30,09	153,00	0,074	0,60 (5,0)	$3,52 \pm 0,33$
$^{32}\text{S}$ 6,69 MeV	58,38	116,94	0,225	0,48 (25)	$3,30 \pm 1,00$
$^{32}\text{S}$ 3,78 MeV	59,19	104,96	0,210	0,32 (37)	$5,17 \pm 3,36$
	58,80	104,96	0,209	0,27 (45)	$4,40 \pm 3,30$
$^{40}\text{Ca}$ 3,35 MeV	53,98	140,95	0,250	0,92 (9)	$3,03 \pm 1,21$

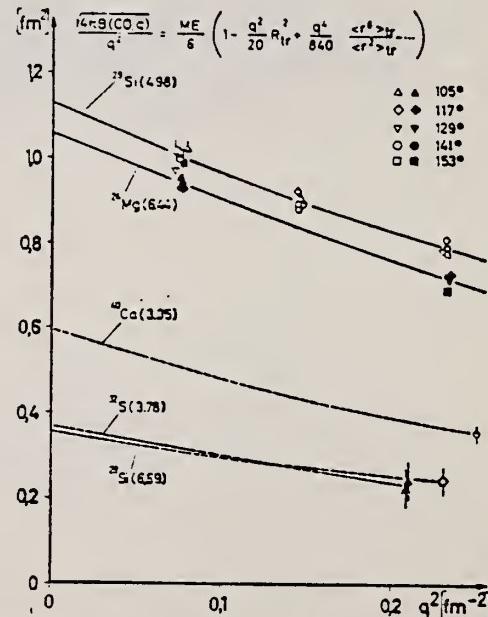


Fig. 3. Meßergebnisse für Monopolübergänge in  $^{24}\text{Mg}$ (6,44 MeV),  $^{28}\text{Si}$ (4,98 und 6,69 MeV),  $^{32}\text{S}$ (3,78 MeV) und  $^{40}\text{Ca}$ (3,35 MeV) als Funktion von  $q^2$ . Die eingebrachten Meßpunkte und die zugehörigen Kurven gelten für eine Auswertung mit  $f_c$ ,  $x_1$  und  $x_2$  nach Modell I. Für  $^{28}\text{Si}$ (4,98) sind nur die aus  $\sigma/\sigma_E$  und  $D_{BA}^{\exp}$  berechneten longitudinalen Anteile aufgetragen (vgl. 5.1), wobei die Meßpunkte bei gleicher Impulsübertragung und gleichem Streuwinkel (vgl. Tabelle 3) zusammengefaßt wurden. Die gestrichelten Kurven zeigen die Extrapolation nach  $q=0$  mit vorgegebenem Übergangsradius

ELEM. SYM.	A	Z
Mg	24	12
REF. NO.	70 We 1	egf

METHOD

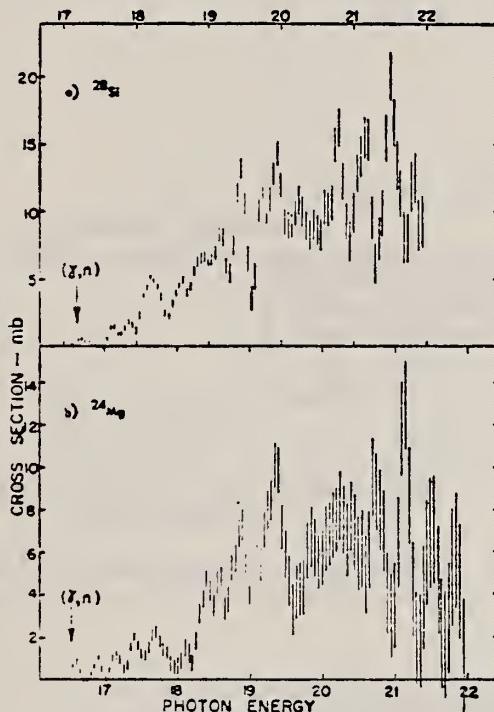


Fig. 2. Analysis of the  $J_\pi = 50$  keV data to 22 MeV in  $\Delta_\pi = 100$  keV bins for the photoneutron cross sections of (a) silicon and (b) magnesium.

TABLE 3  
Integrated cross sections for magnesium

Source	$\int_0^{24} \text{MeV} \sigma dE (\text{MeV} \cdot \text{mb})$	$\int_0^{31} \text{MeV} \sigma dE (\text{MeV} \cdot \text{mb})$
this experiment	35 ± 4	72 ± 7 (62.8 ± 6 to 29 MeV)
Fultz et al. <sup>24)</sup>	33.7	66.8 (to 29 MeV)
Anderson et al. <sup>27)</sup>	52	115
Miller et al. <sup>25)</sup>	45 ± 7	
Min and Whitehead <sup>26)</sup>	60	

- <sup>24)</sup>S.C. Fultz, J.T. Caldwell,  
B.L. Berman, R.R. Harvey and  
M. Kelly, Bull.Am.Phys.Soc.  
14 (1969) 103.  
<sup>25)</sup>J. Miller, C. Schul, G. Tamas  
and C. Tzara, J.de Phys.27 (1966)8.  
<sup>26)</sup>K. Min and W.D. Whitehead, Phys.  
Rev. 137B (1965)301.  
<sup>27)</sup>D.W. Anderson, B.C. Cook and  
T.J. Englert, Nucl. Phys. A127  
(1969) 474.

[ over ]

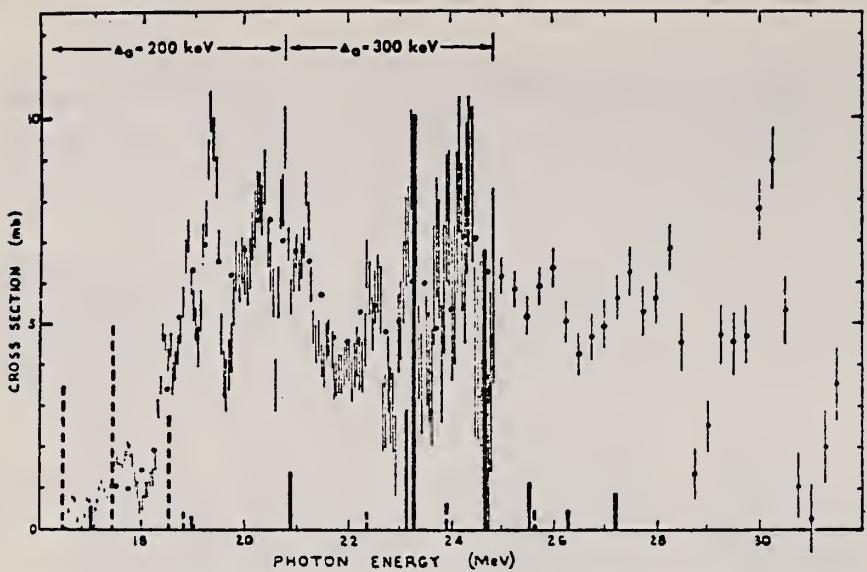


Fig. 5. The photoneutron cross section for natural magnesium. The full circles indicate the coarse resolution measurement ( $\Delta_e = 250$  keV,  $\Delta_s = 500$  keV). The higher resolution measurement ( $\Delta_e = 50$  keV,  $\Delta_s = 200$  keV) is presented by the error bars up to 25 MeV. The predictions of Nilsson *et al.*<sup>9</sup>) are shown by the heavy dashed ( $K = 0$ ) and continuous ( $K = 1$ ) bars.

<sup>9</sup>) S.G. Nilsson, J. Sawicki and N.K. Glendenning, Nucl. Phys. 33 (1962) 239.

REF.

R. J. Baglan, C. D. Bowman and B. L. Berman  
 Phys. Rev. C2, 672 (1971)

ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.

71 Ba 2

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N	ABX	16 - 20	C	17,20	TOF-D		135
		(16.6 - 19.5)					

941

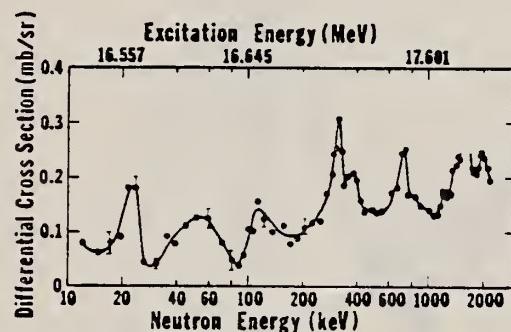


FIG. 15. The 135° differential threshold photoneutron cross section for  $^{24}\text{Mg}$  (see caption to Fig. 4).

FIG. 4. The 135° differential threshold photoneutron cross section for  $^{207}\text{Pb}$  at low energies versus the energy of the emitted neutron (lower scale) and the excitation energy (upper scale). The arrows indicate peaks which decay to excited states of the residual nucleus (ES), or peaks owing to contaminating isotopes in the photoneutron sample. The inset shows the  $^{207}\text{Pb}(\gamma, n)$  cross section averaged with a square 40-keV wide smoothing function.

Also see:

R. J. Baglan et al.  
 Phys. Rev. C2, 2475  
 (1971)

[over]

TABLE VII. Resonance parameters for  $^{24,25,26}\text{Mg}$ ,  $^{19}\text{F}$ , and  $^{31}\text{P}$ . For all resonances, the area under the peak in the  $135^\circ$  differential cross section is multiplied by  $4\pi$  to yield approximate values for  $g_\gamma \Gamma_{\gamma_0} \Gamma_n / \Gamma \approx g_\gamma \Gamma_{\gamma_0}$ . For those resonances where  $J^\pi$  is known, the differential area is multiplied by the appropriate factor  $F$  from Table I to obtain  $\Gamma_{\gamma_0}$ .  $E_L$  is the laboratory neutron energy for the  $(\gamma, n)$  reaction and  $E_n$  is the corresponding laboratory neutron energy for a neutron-induced reaction. Column 5 labels the peak as a ground-state (GS) or excited-state (ES) transition as determined in this work alone.

Nucleus	$E_L$ (keV)	$E_{ex}$ (MeV)	$g_\gamma \Gamma_{\gamma_0} \Gamma_n / \Gamma$ (eV)	GS or ES	$J^\pi$	$\Gamma_{\gamma_0}$ (eV)	$E_n$ (keV) (This work)
$^{24}\text{Mg}$	22	16.559	0.61	GS	$(1^-)$	0.40	28
	55	16.596	2.4		$(1^-)$	1.6	66
	110	16.656	4.0		$(1^-)$	2.7	128
	312	16.871	10.7		$(1^-)$	7.1 <sup>a</sup>	354
	382	16.95					432
	717	17.30	19.5		$(1^-)$	13.0 <sup>a</sup>	804
	1210	17.83					1348
	1620	18.26					1799
	1955	18.61					2168
							46.8
$^{25}\text{Mg}$	41.1	7.374	0.09	GS			
	45.1	8.746	0.31		ES		
	74.9	7.410	0.36		$\frac{3}{2}^-$ <sup>b</sup>	1.1	84.1 <sup>b</sup>
	208	8.920	0.29		ES		
	236	7.580	0.09		GS		261
	404	7.756	0.03				445
	439	7.793	0.05		$\frac{5}{2}^+$ <sup>c</sup>		484
	472	7.828	0.06				520
	515	7.873	0.46		GS	$\frac{3}{2}^+$ <sup>c</sup>	567
	601	7.964	0.18				661
	781	8.152	1.51		GS		857
	912	8.292	0.72				1003
	1236	9.999	2.4 <sup>c</sup>		ES	$\frac{3}{2}^+$ or $\frac{5}{2}^+$ <sup>c</sup>	
	1707	9.12					1869
	1764	9.18					1931
$^{26}\text{Mg}$	54.3	11.155	2.6	GS	$1^-(1^+, 2^+)$	1.75	62.3
	63.2	11.164	0.05			0.034	72.2
	181	11.289	1.0		$1^-(1^+, 2^+)$	0.68	202
	222	11.333	1.9		$1^-(1^+, 2^+)$	1.3	248
	391	11.511	5.1		$1^-(1^+, 2^+)$	3.5	433
	621	11.753	32.5		$1^-(1^+, 2^+)$	22.2	684
	738		15.0 <sup>d</sup>		ES	5.1	
	1122	12.279	14.7		GS	$1^-(1^+, 2^+)$	1232
$^{19}\text{F}$	100	10.542	1.8	GS			118
$^{31}\text{P}$	109	12.429	0.86			121	
	280	12.609	0.60			307	
	398	12.732	0.59			434	
	678	13.026	0.90			737	
	939	13.297	4.4				1013

<sup>a</sup>These values for  $\Gamma_{\gamma_0}$ , when increased by approximately a factor of 2 in order to include the relatively high cross sections in the valleys, agree very well with corresponding values from Ref. 8 (see Ref. 4).

<sup>b</sup>This resonance was seen at  $E_n = 83$  and 84 keV in Refs. 24 and 25, respectively.

<sup>c</sup>Analogs of states in  $^{25}\text{Na}$  (see text). The value for  $g_\gamma \Gamma_{\gamma_0} \Gamma_n / \Gamma$  given in Ref. 26 was not corrected with the multiplicative factor in Table II.

<sup>d</sup>Assuming a first-excited-state transition.

<sup>4</sup>R.L. Van Hemert, C.D. Bowman, R.J. Baglan, and B.L. Berman (to be published); R.L. Van Hemert, University of California Lawrence Radiation Laboratory Report No. UCRL-50442, 1968 (unpublished).

<sup>8</sup>S.C. Fultz, M.A. Kelly, J.T. Caldwell, R.R. Harvey, and B.L. Berman, Bull. Am. Phys. Soc. 14, 103 (1969), and private communication.

<sup>24</sup>H.W. Newson, R.C. Block, P.F. Nichols, A. Taylor, A.K. Furr, and E. Merzbacher, Ann. Phys. (N.Y.) 8, 211 (1959).

<sup>25</sup>D.J. Hughes and R.B. Schwartz, Neutron Cross Sections (U.S. Government Printing Office, Washington, D.C., 1966), 2nd ed., 2nd Suppl., Vol. IIc.

REF. S.C. Fultz, R.A. Alvarez, B.L. Berman, M.A. Kelly, D.R. Lasher,  
T.W. Phillips, J. McElhinney  
Phys. Rev. C4, 149 (1971)

ELEM. SYM.	A	Z
Mg	24	12
REF. NO.		
71 Fu 2		hm <sub>g</sub>
ECTOR		ANGLE
RANGE		4PI
		343

## 14 LEVEL FIT

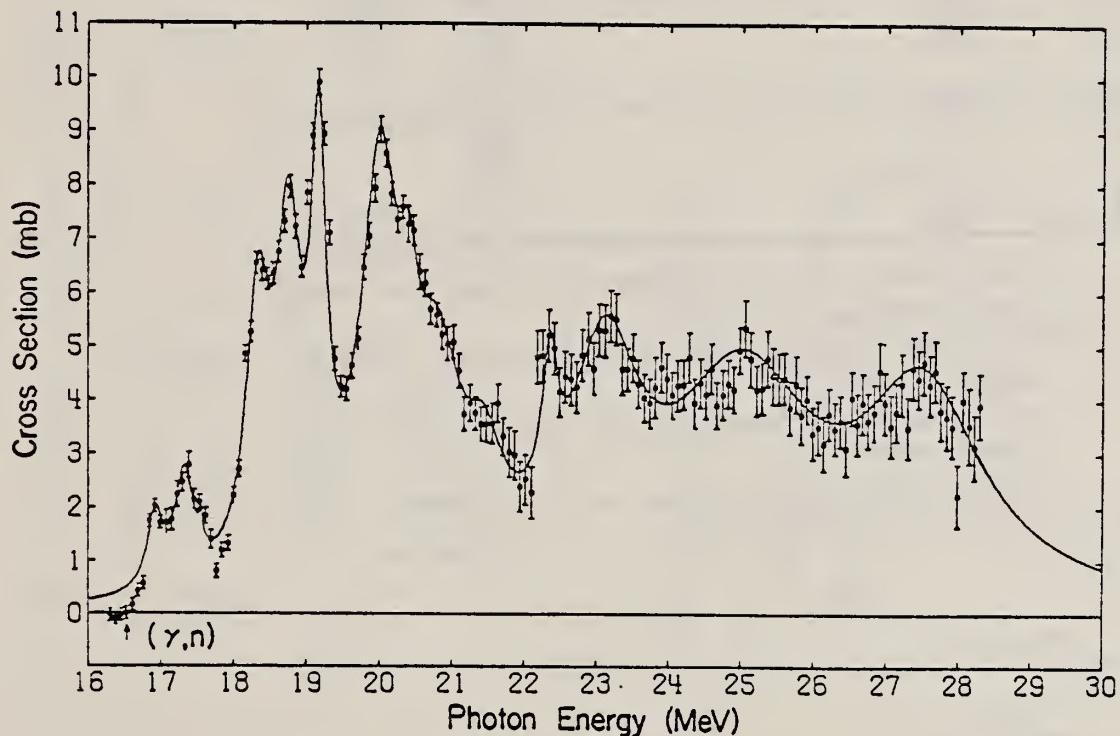


FIG. 3.  $^{24}\text{Mg}$  total cross section  $\sigma(\gamma, n) + (\gamma, p\pi)$ ) fitted with a calculated cross-section curve. The solid line is the sum of the 14 Lorentz lines whose parameters were adjusted to fit the data.

TABLE II. Integrated cross sections of magnesium isotopes.

Isotope	$\int_{E_{\text{thr}}}^{28} \sigma(\gamma, n_{\text{tot}}) dE$ (MeV mb)	$\int_{E_{\text{thr}}}^{28} \sigma(\gamma, 2n) dE$ (MeV mb)
$^{24}\text{Mg}$	50	...
$^{26}\text{Mg}$	226	68
Natural magnesium	76	...

[over]

TABLE III. Analytical and experimental resonance energies for  $^{24}\text{Mg}$  (MeV).

Resonance number	Analytical energy	Present data ( $\gamma, n_{\text{tot}}$ )	Experimental energies			
			Livermore (Ref. 15) ( $\gamma, n_0$ )	Yale (Ref. 14) ( $\gamma, n_0$ )	Darmstadt (Ref. 12) ( $e, e'$ )	Argonne (Ref. 2) ( $\gamma, p_0$ )
1	16.92	16.90	16.871 16.95		16.90 17.08	16.9 17.2
2	17.32	17.30	17.30		17.33	17.35
3	17.55	17.65	17.83	17.83	17.60	17.5
				17.95	17.90	
				18.15	18.21	
4	18.33	18.30	18.26	18.36	18.50	18.25
5	18.75	18.82	18.61	18.58	18.85	18.5
6	19.16	19.17		19.21	19.23	19.0
				19.48		19.3
7	20.00	20.05		19.95	20.10	20.1
8	20.40	20.36			20.35	20.4
9	20.80	20.90			20.77	20.7
					21.16	
10	21.45	21.45			21.50	
11	22.35	22.35			22.28	
12	23.10	23.10			23.02	
					23.42	
13	25.00	25.00			25.05	
14	27.50	27.50				

<sup>2</sup>R.C. Bearse, L. Meyer-Schutzmeister, and R.E. Segel,  
Nucl. Phys. A116, 682 (1968).

<sup>12</sup>O. Titze, E. Spamer, and A. Goldman, Phys. Letters 24B, 169 (1967).

<sup>14</sup>C.-P. Wu, Ph.D. Thesis, Yale University, 1968  
(unpublished).

<sup>15</sup>R. J. Baglan, C. D. Bowman, and B. L. Berman,  
Phys. Rev. C3, 672 (1971).

METHOD

REF. NO.

71 Ho 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	FMF	1, 4	D	183, 250	MAG-D		DST

1.37, 4.12 MEV

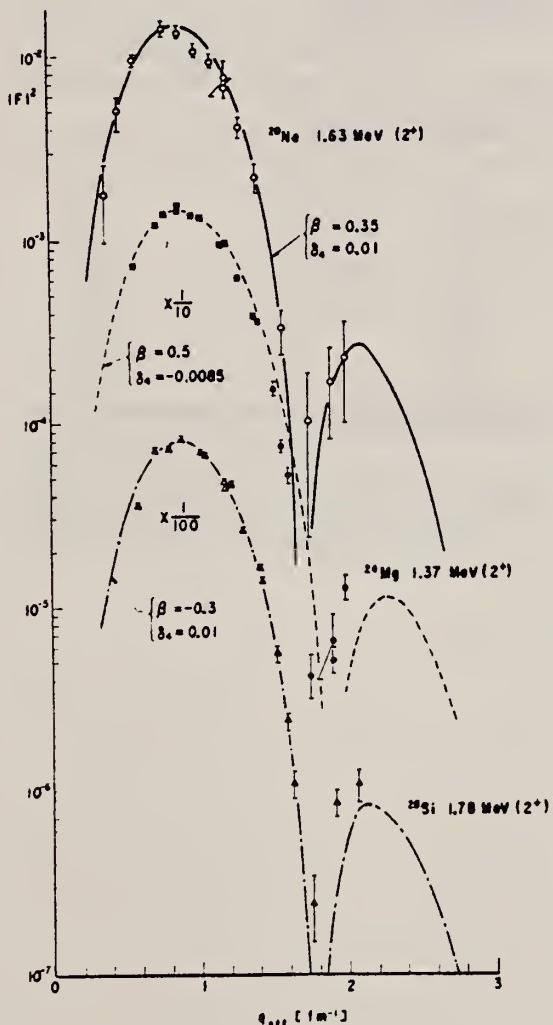


Fig.1. The experimental form factors for the  $2^+$  members of the ground-state rotational bands in  $^{20}\text{Ne}$ ,  $^{24}\text{Mg}$  and  $^{28}\text{Si}$  are shown as a function of the  $q_{\text{eff}}$  [3].

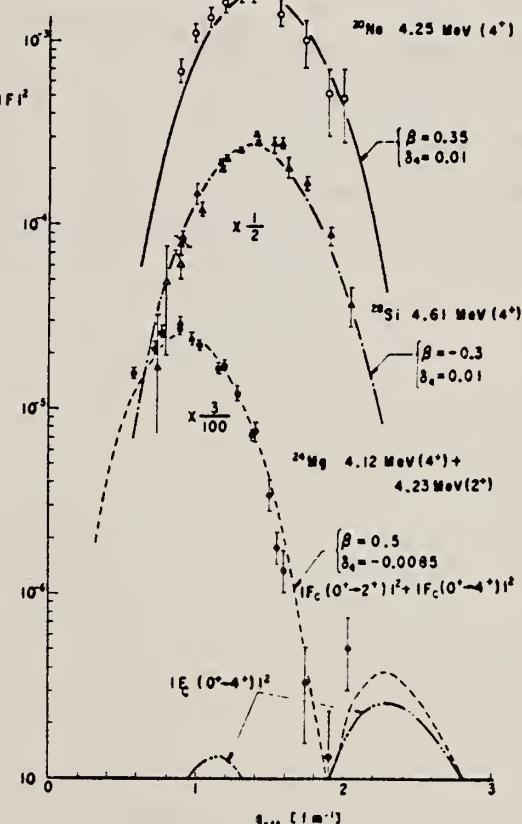


Fig.2. The same as for fig.1 except for the  $4^+$  members. The unresolved data of the 4.12 MeV ( $4^+$ ) and 4.23 MeV ( $2^+$ ) states is presented in the case of  $^{24}\text{Mg}$ .

- (2) R. de Swiniarski, D. Glashausser, D. L. Hendrie, J. Sherman, A. D. Bacher,  
and E. A. McClatchie, Phys. Rev. Letters 23 (1964) 317.  
(3) D. G. Ravenhall, quoted in: R. Hofstater, Rev. Mod. Phys. 28 (1956) 214.  
(5) H. Rebel, G. W. Schweimer, J. Specht, G. Schatz, R. Lohken, D. Habs,  
G. Hanser and H. Klewe-Nebenius, Phys. Rev. Letters 26 (1971) 1190.

Table 1

The values obtained from the Nilsson orbits which provide the best fit form factors. The signs of the moments were determined by the characteristic of the orbits. The  $\beta_2$  and  $\beta_4$  values of the present study are compared with those of the  $(p, p')$  [2] and  $(\alpha, \alpha')$  [5] reactions.

	$\langle r^2 \rangle^{1/2}$ (fm)	$\langle r^4 \rangle^{1/4}$ (fm)	$Q_0$ (efm <sup>2</sup> )	$H_0$ (efm <sup>4</sup> )	$\beta_2$		$\beta_4$	
					present (e, e')	(p, p') ( $\alpha, \alpha'$ )	present (e, e')	(p, p') ( $\alpha, \alpha'$ )
<sup>20</sup> Ne	2.91	3.14	+58 ± 3	+249 ± 27	+0.40	+0.47	+0.35 ±0.01	+0.19 ±0.05
<sup>24</sup> Mg	3.03	3.24	+69 ± 3	+ 48 ± 16	+0.45	+0.47	-0.06 ±0.08	-0.05 ±0.08
<sup>28</sup> Si	3.14	3.35	-64 ± 3	+205 ± 33	-0.39	-0.37	-0.32 ±0.01	+0.10 ±0.08
							+0.25 ±0.08	+0.08 ±0.01

REF.

E. J. Moniz, I. Sick, R. R. Whitney, J. R. Ficenec, R. G. Kephart  
and W. P. Trower  
Phys. Rev. Letters 26, 445 (1971)

ELEM. SYM.

Mg

24

12

Z

METHOD

REF. NO.

71 Mo 3

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	ABX	0-240	D	500	MAG-D		60

Table I. Nuclear Fermi momentum  $k_F$  and average nucleon interaction energy  $\bar{\epsilon}$  determined by least-squares fit of theory to quasielastic peak.

Nucleus	$k_F$ (MeV/c) <sup>a</sup>	$\bar{\epsilon}$ (MeV) <sup>b</sup>
<sup>3</sup> Li <sup>6</sup>	160	17
<sup>6</sup> C <sup>12</sup>	221	25
<sup>12</sup> Mg <sup>24</sup>	235	32
<sup>20</sup> Ca <sup>40</sup>	251	28
<sup>28</sup> Ni <sup>58.7</sup>	260	36
<sup>39</sup> Y <sup>89</sup>	254	39
<sup>50</sup> Sn <sup>118.7</sup>	260	42
<sup>73</sup> Ta <sup>181</sup>	265	42
<sup>82</sup> Pb <sup>208</sup>	265	44

<sup>a</sup>The fitting uncertainty in these numbers is approximately  $\pm 5$  MeV/c.

<sup>b</sup>The fitting uncertainty in these numbers is approximately  $\pm 3$  MeV. Simple estimates for  $\bar{\epsilon}$  give numbers in reasonable agreement with those in the table.

ELEM. SYM.	A	Z
Mg	24	12

## METHOD

REF. NO.

71 Sw 2

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	1 (1.368)	D	1 (1.468)	SCD-D		127

1.368 MEV 2+ STATE

A mean life of  $1.92 \pm 0.15$  psec has been obtained for the 1.368-MeV 2<sup>+</sup> state of <sup>24</sup>Mg by comparing the resonant scattering of  $\gamma$  rays through the <sup>24</sup>Mg level and through the 1.333-MeV 2<sup>+</sup> state of <sup>60</sup>Ni, the lifetime of which is known accurately. This value is in good agreement with recent Coulomb-excitation results but differs markedly from a recent resonance-fluorescence self-absorption result.

TABLE I. Mean lifetime of the 1.368-MeV level of <sup>24</sup>Mg.

Method	$\tau$ (psec)	Reference
Resonance-fluorescence scattering	$1.92 \pm 0.15$	Present
Resonance-fluorescence scattering	$1.95 \pm 0.26$	3
Resonance-fluorescence scattering	$1.11 \pm 0.13$	2
Inelastic electron scattering	$1.9 \pm 0.2$	5
Coulomb excitation	$2.00 \pm 0.10$	1
Coulomb excitation	$2.04 \pm 0.14$	4

B. S. Ishkhanov, I. M. Kapitonov, E. V. Lazutin, I. M. Piskarev,  
and V. G. Shevchenko  
*Nucl. Phys.* A186, 438 (1972)

ELEM. SYM.	A		
Mg	24	12	

METHOD

REF. NO.

72 Is 1

egf

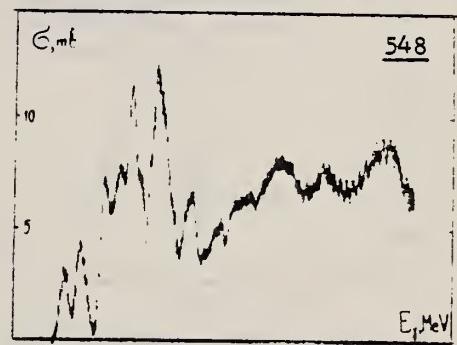
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,XN	ABX	16-30	C	16-30	BF3-I		4PI

548

TABLE 2

The maxima of the fine structure of the giant resonance in  $^{24}\text{Mg}$  and the corresponding resonances of intermediate structure

Ref. <sup>10</sup> )	Ref. <sup>11</sup> )	Ref. <sup>10</sup> )	Present work	Resonances of intermediate structure (MeV)
16.52		16.6		
16.90	16.92	17.0	$16.85 \pm 0.08$	
(17.08)				
17.33	17.32	17.2	$17.40 \pm 0.08$	17
(17.60)	(17.55)	17.6		
17.90		17.8		
(18.21)				
18.50	18.33	18.5	$18.30 \pm 0.09$	
18.85	18.75	18.9	$18.85 \pm 0.09$	19
19.23	19.16	19.3	$19.30 \pm 0.10$	
19.74				
20.10	20.00	20.3	$20.20 \pm 0.10$	
20.35	20.40			
(20.77)	(20.80)	20.7		20-21
(21.16)		21.2		
(21.50)	21.45		$21.45 \pm 0.13$	
22.28	22.35	22.5	$22.50 \pm 0.15$	
(23.02)	23.10	23.2	$23.35 \pm 0.15$	23
(23.42)				
(24.06)		24.1		
25.05	25.00	(25.8)	$24.6 \pm 0.2$ $26.3 \pm 0.2$	25

<sup>10</sup>D.V. Webb *et al.*, *Nucl. Phys.* A159 (1970) 81<sup>12</sup>S.C. Fultz *et al.*, *Phys. Rev. C4* (1971) 149<sup>16</sup>O. Titze *et al.*, *Phys. Lett.* 24B (1967) 169Fig. 1. Cross section for  $^{24}\text{Mg}(\gamma, n) + (\gamma, np)$ .

METHOD				REF. NO.	
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
E, E/	LFT	1-6	D	183-250	DST

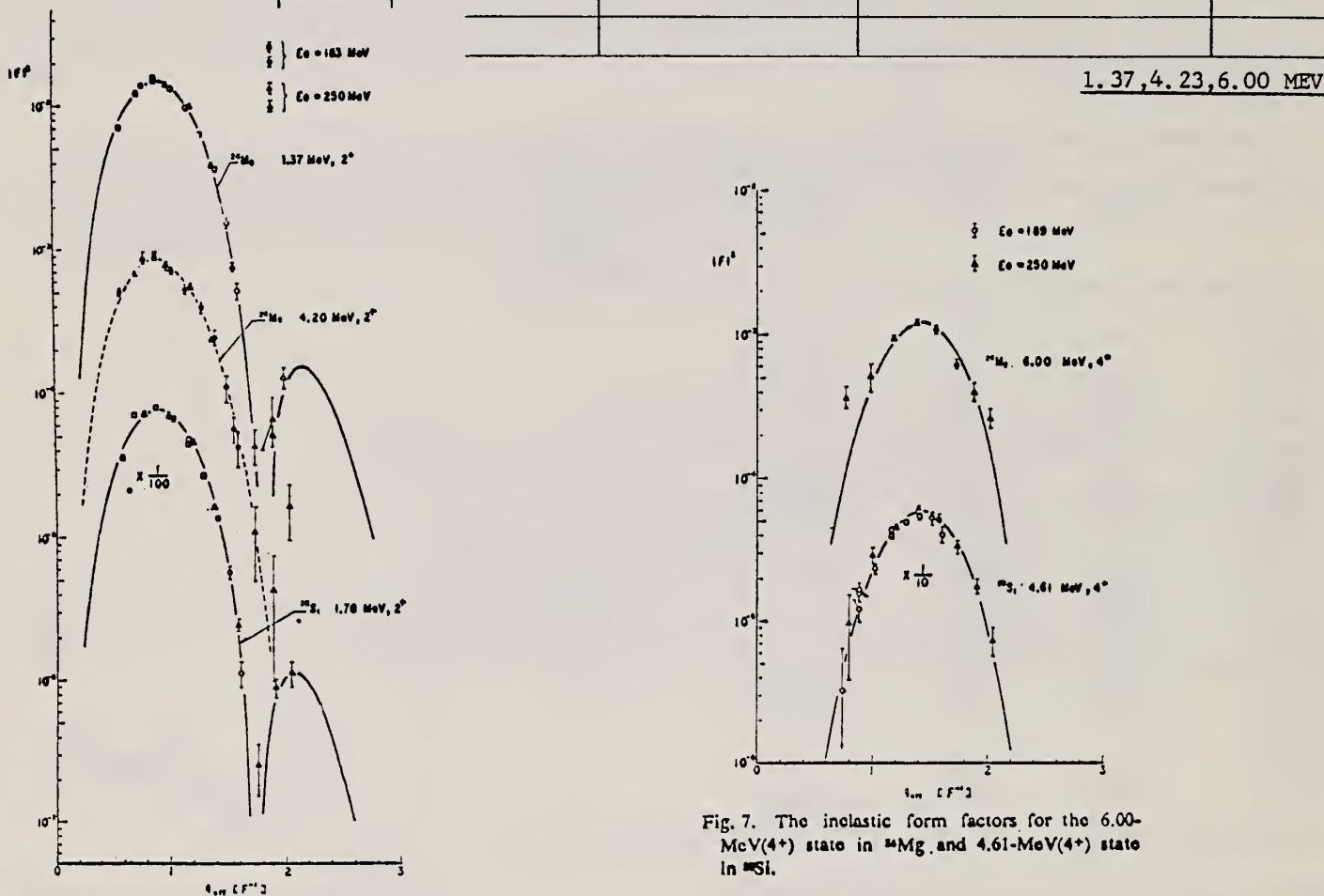


Fig. 5. The inelastic form factors for the 1.37-(2+), 4.20-MeV (2+) states in  $^{24}\text{Mg}$  and for the 1.78-MeV (2+) in  $^{28}\text{Si}$  are shown as a function of  $q_{\text{ex}}$ . The curves are the best fit form factors calculated with the Born approximation.

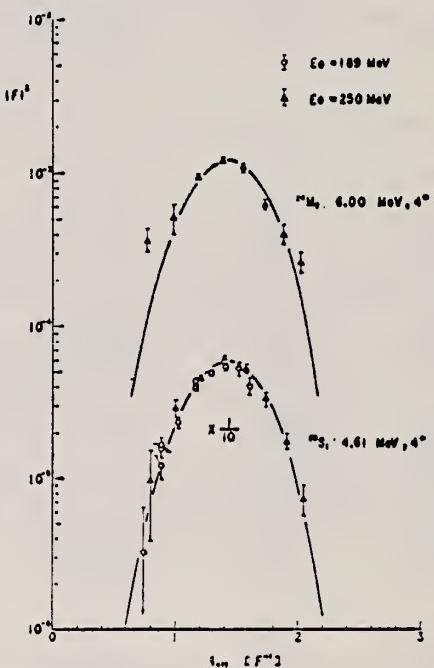


Fig. 7. The inelastic form factors for the 6.00-MeV(4+) state in  $^{24}\text{Mg}$  and 4.61-MeV(4+) state in  $^{28}\text{Si}$ .

Table II. The  $B(EL)$  values extracted from the experimental form factors.

Nucleus	$E_x$ (MeV)	$J^\pi$	Born approx.		DWBA	
			$B(EL)$ (W.U.)	$B(EL)$ ( $\text{e}^2 \text{F}^{2L}$ )	$B(EL)$ (W.U.)	$B(EL)$ ( $\text{e}^2 \text{F}^{2L}$ )
$^{24}\text{Mg}$	1.37	2+	$18.1 \pm 1.7$	$(3.27 \pm 0.35) \times 10^3$	$21.7 \pm 2.2$	$(4.46 \pm 0.45) \times 10^3$
	4.23	2+	$1.11 \pm 0.18$	$(2.28 \pm 0.37) \times 10^1$		
	6.00	4+	10.6	$2.87 \times 10^4$		
$^{28}\text{Si}$	1.78	2+	$11.1 \pm 1.5$	$(2.80 \pm 0.38) \times 10^3$	$13.7 \pm 1.3$	$(3.46 \pm 0.33) \times 10^3$
	4.61	4+	$4.35 \pm 0.49$	$(1.78 \times 0.20) \times 10^4$		
	6.88	3-	$8.99 \pm 0.71$	$(2.93 \pm 0.23) \times 10^3$		
	9.70	3-	$1.88 \pm 0.30$	$(6.13 \pm 0.98) \times 10^3$		

REF.

A.H. Chung, W.T. Diamond, A.E. Litherland, H.L. Pai,  
and J. Goldemberg  
Phys. Lett. 53B, 244 (1974)

ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.  
74 Ch 9

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,C12	NOX	24- 29	D	25- 29	TRK-I		DST

$$\int_{24}^{29} \sigma dE \geq 3.0 \pm 0.6 \text{ } \mu\text{b-MeV}$$

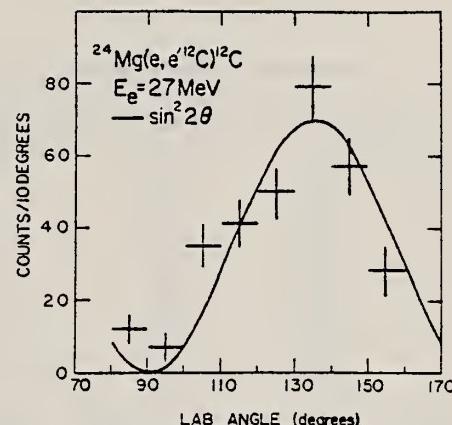


Fig. 1. The angular distribution of ground-state carbon nuclei from the electron induced fission of  $^{24}\text{Mg}$  at  $E_e = 27 \text{ MeV}$  is shown together with the function  $\sin^2 2\theta$ .

The electron induced fission of  $^{24}\text{Mg}$  leading to the ground states of two carbon nuclei has been studied using 25 to 45 MeV electrons. The observed  $\sin^2 2\theta$  angular distribution of the carbon nuclei indicates the dominance of E2 virtual photon absorption. The yield of ground state carbon nuclei is observed to decrease with increasing excitation energy in  $^{24}\text{Mg}$  above 24 MeV.



ELEM. SYM.	A	Z
Mg	24	12
REF. NO.		
74 Jo 4		egf
METHOD		

REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE	RANGE	
E,E/	LFT	1- 14	D	64-116	MAG-D
					DST

$F^2(q)$ ,  $F_T^2(q)$  plots given.

19 STATES

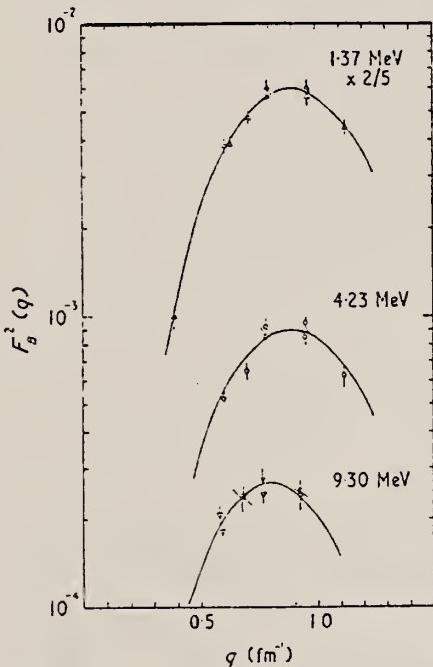


Figure 5.  $F_n^2(q)$  for the  $2^+$  states at 1.37 MeV, 4.23 MeV and 9.30 MeV.

Table 1. Kinematics of the experimental runs.

Run Number	Energy (MeV)	Angle (deg)	$q_{EL}(\text{fm}^{-1})$
1	91.50	120.0	0.80
2	81.66	154.0	0.80
3	110.82	120.0	0.97
4	99.21	153.0	0.97
5	64.94	154.0	0.64
6	70.92	120.0	0.62
7	73.81	153.0	0.72
8	110.07	80.0	0.72
9	115.67	153.0	1.14
10	72.6	65.0	0.40

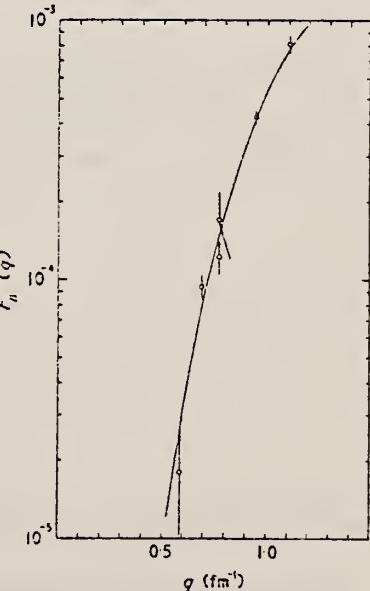


Figure 6.  $F_n^2(q)$  for the  $4^+$  state at 6.00 MeV.

(over)

Table 5. Results for the states with  $E_x < 11$  MeV.

$E_x$ (MeV)	$J^\pi$	Tassie model				Helm model		
		$c$ (fm)	$t$ (fm)	$B(XL\uparrow)e^2 \text{ fm}^{2L}$	$R_{tr}$ (fm)	$R$ (fm)	$B(XL\uparrow)e^2 \text{ fm}^{2L}$	$R_{tr}$ (fm)
1.37	$2^+$	2.88	2.06	$420 \pm 25$	$4.11 \pm 0.08$	3.03	$411 \pm 23$	$4.03 \pm 0.07$
4.23	$2^+$	2.91	2.08	$26.3 \pm 6.0$	$4.14 \pm 0.30$	3.10	$25.5 \pm 4.0$	$4.09 \pm 0.20$
6.00	$4^+$	2.48	1.93	$(4.2 \pm 1.0) \times 10^4$	$4.90 \pm 0.70$	3.0	$(3.6 \pm 1.0) \times 10^4$	$4.50 \pm 0.50$
6.43	$0^+$					5.14	$6.7 \pm 0.4(\text{ME})$	$6.05 \pm 0.20$
7.59	$3^-$	2.68	2.08	$(1.36 \pm 0.22) \times 10^3$	$4.57 \pm 0.40$	3.17	$(1.30 \pm 0.16) \times 10^3$	$4.39 \pm 0.22$
8.37	$3^-$	2.61	2.09	$(2.0 \pm 0.2) \times 10^3$	$4.55 \pm 0.38$	3.03	$(1.80 \pm 0.20) \times 10^3$	$4.28 \pm 0.22$
9.30	$2^+$	3.18	2.36	$12.0 \pm 2.0$	$4.62 \pm 0.30$	3.56	$11.3 \pm 1.5$	$4.45 \pm 0.19$
9.97	$1^+$	2.45	2.90	$(1.38 \pm 0.20) \times 10^{-2}$	$2.83 \pm 0.30$		$(1.34 \pm 0.15) \times 10^{-2}$	$2.70 \pm 0.20$
10.35	$4^+$					3.0	$(1.2 \pm 0.4) \times 10^4$	4.5
10.70	$1^+$	2.64	2.90	$(3.11 \pm 0.40) \times 10^{-2}$	$2.91 \pm 0.40$		$(3.15 \pm 0.30) \times 10^{-2}$	$2.74 \pm 0.30$

Table 6. Results for the states with  $E_x > 11$  MeV.

$E_x$ (MeV)	$J^\pi$	Helm model			
		$R$ (fm)	$\gamma^0$	$B(XL\uparrow)e^2 \text{ fm}^{2L}$	$R_{tr}$ (fm)
11.1	$3^-$	3.03†	2.0	$6.2 \times 10^2$	4.3
11.38	$2^+$	3.10†	$0.4 \pm 0.2$	$2.5 \pm 0.7$	4.1
11.86	$(1^-, 3^-)$	3.03†	—	$2.6 \times 10^{-6}(\text{E1})$ $(3.4 \pm 0.5) \times 10^2(\text{E3})$	4.3
11.99	$3^-$	3.03†	$1.0 \pm 0.2$	$(1.4 \pm 0.2) \times 10^2$	4.3
12.39	$3^-$	3.03†	—	$(2.0 \pm 0.2) \times 10^2$	4.3
12.52	$2^+$	3.10†	$0.63 \pm 0.05$	$2.2 \pm 0.4$	4.1
12.7†	$2^-$	$0.42 \pm 0.08$	$1.6 \pm 0.3$	$0.26 \pm 0.10$	$2.5 \pm 1.0$
12.99	$2^+$	3.10†	$0.85 \pm 0.05$	$3.7 \pm 0.6$	4.1
13.37†	$2^-$	$0.63 \pm 0.11$	$2.2 \pm 0.4$	$0.58 \pm 0.20$	$2.5 \pm 1.0$

† Parameter fixed at value obtained for a lower energy transition of the same multipolarity.

‡  $\gamma^-$  and  $\gamma^+$  are given under  $R$  and  $\gamma^0$  respectively.

ELEM. SYM.	A	Z
Mg	24	12

## METHOD

REF. NO.

74 Li 2

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,E/	FMF	1- 6	C	250,500	MAG-D		DST

Detailed elastic scattering data tables for  
 $^{24}\text{Mg}$ ,  $^{27}\text{Al}$ ,  $^{28}\text{Si}$ , and  $^{32}\text{S}$ .

4 LEVELS 1.37 to 6.00

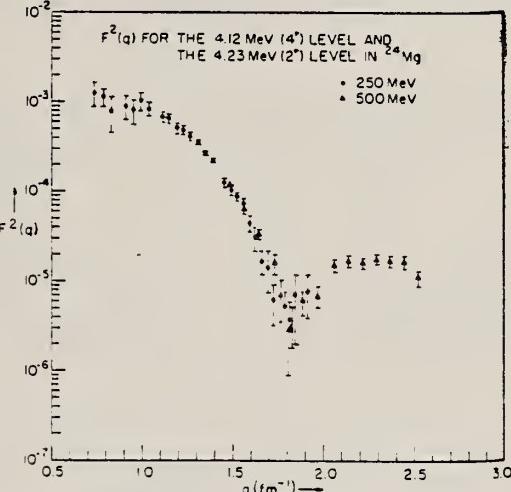


FIG. 10. Experimental form factor of the 4.12-MeV (4<sup>+</sup>) and the 4.23-MeV (2<sup>+</sup>) levels in  $^{24}\text{Mg}$ .

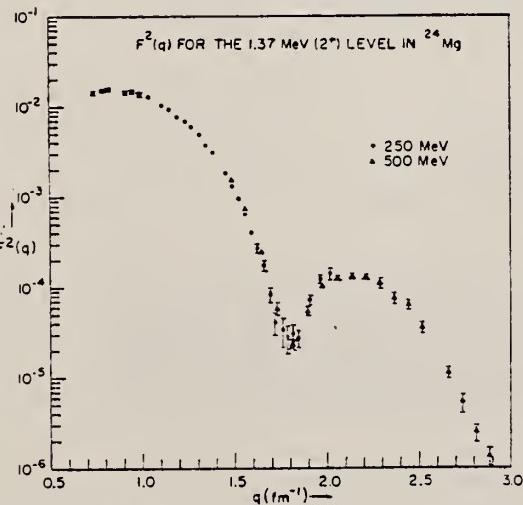


FIG. 9. Experimental form factor of the 1.37-MeV (2<sup>+</sup>) level in  $^{24}\text{Mg}$ .

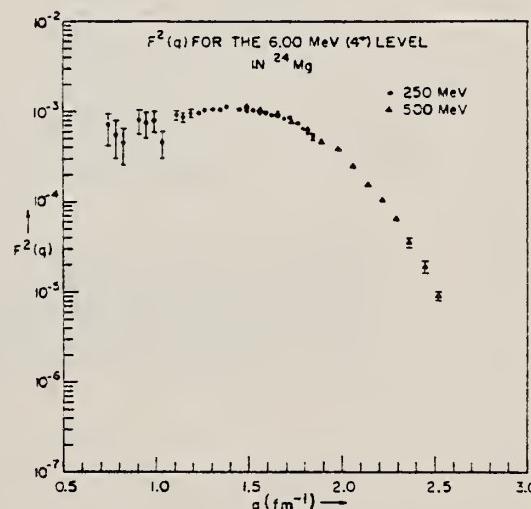


FIG. 11. Experimental form factor of the 6.00-MeV (4<sup>+</sup>) level in  $^{24}\text{Mg}$ .



ELEM. SYM.	A	Z
Mg	24	12
REF. NO.		
74 Wh 3		hmg
ECTOR		ANGLE
RANGE		60

See further analysis of this data in reference 79Zil

QUASIELASTIC SCAT

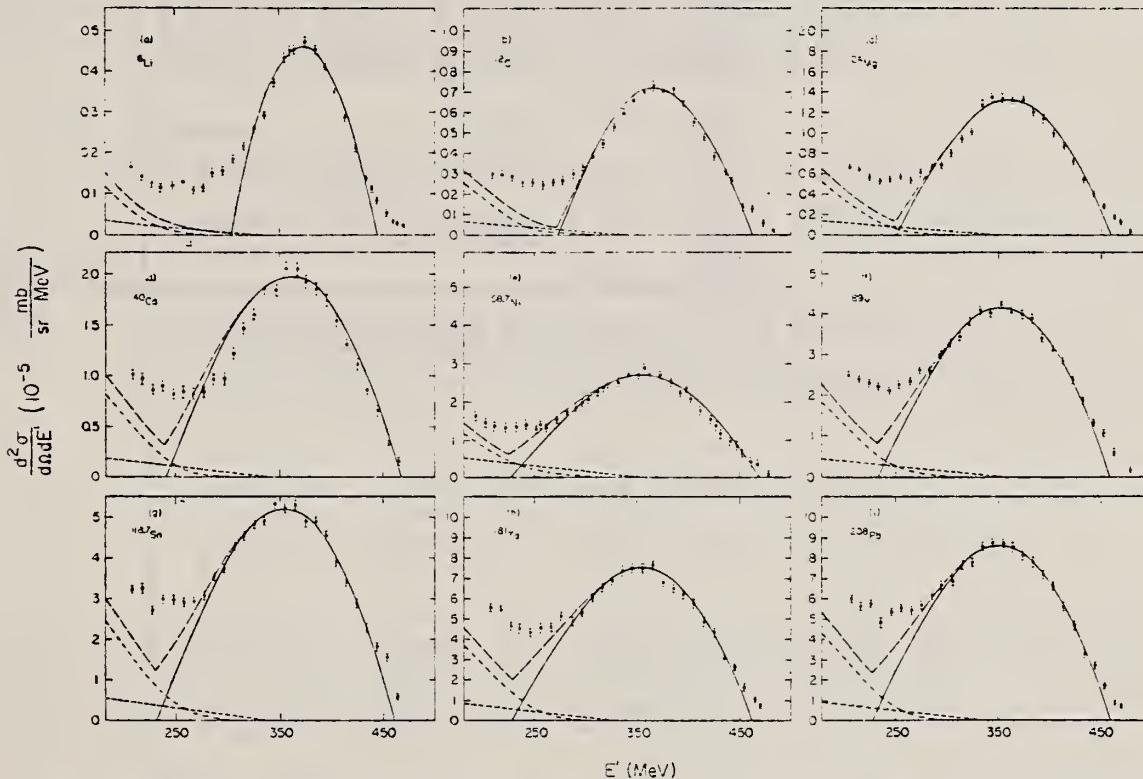


FIG. 1. The measured quasielastic peaks; the errors on the data points do not include an over-all 3% normalization uncertainty. The solid curve is a fit by the Fermi-gas model which yielded  $k_F$  (in MeV/c) and  $\bar{\epsilon}$  (in MeV) as follows: (a)  $^6\text{Li}$  (169, 17); (b)  $^{12}\text{C}$  (221, 25); (c)  $^{24}\text{Mg}$  (235, 32); (d)  $^{40}\text{Ca}$  (249, 33); (e)  $^{58,\dagger}\text{Ni}$  (260, 36); (f)  $^{89}\text{Y}$  (254, 39); (g)  $^{118,\ddagger}\text{Sm}$  (260, 42); (h)  $^{181}\text{Ta}$  (265, 42); (i)  $^{208}\text{Pb}$  (265, 44). The fitting uncertainty in  $k_F$  is  $\pm 5$  MeV/c and in  $\bar{\epsilon}$  it is  $\pm 3$  MeV. The small-amplitude dashed curve is the s-wave  $\pi$ -production contribution, the dot-dashed curve is the isobar excitation, and the large-amplitude dashed curve is the total result.

(over)

TABLE I. Proton-normalized and radiative-corrected cross sections  $d^2\sigma/d\Omega dE' = (N \pm \Delta N) \times 10^{-n}$  in nb/sr MeV, for  $E = 500$  MeV and  $\theta = 60^\circ$ .

$E'$ (MeV)	$^{61}\text{Li}$	$^{7}\text{Li}$	$^{11}\text{B}$	$^{24}\text{Mg}$	$^{40}\text{Ca}$	$^{58}\text{-}^{64}\text{Ni}$	$^{69}\text{Y}$	$^{108}\text{-}^{117}\text{Sn}$	$^{180}\text{-}^{185}\text{Ta}$	$^{208}\text{Pb}$					
$N$	$\Delta N$	$n$	$N$	$\Delta N$	$n$	$N$	$\Delta N$	$n$	$N$	$\Delta N$	$n$	$N$	$\Delta N$	$n$	
480.0	...	1.79	0.13	7	3.83	0.42	7	...	1.22	0.17	6	1.71	0.19	6	
474.0	...	1.02	0.13	7	...	...	...	...	...	...	...	...	...	...	
470.0	1.72	0.18	7	5.75	0.52	7	1.55	0.15	6	3.90	0.29	6	5.85	0.41	6
464.0	2.49	0.29	7	1.38	0.11	6	1.91	0.17	6	4.48	0.33	6	5.68	0.37	6
460.0	2.96	0.30	7	1.20	0.09	6	2.56	0.19	6	...	...	...	8.32	0.71	6
454.1	5.02	0.17	7	9.21	0.71	7	2.96	0.20	6	7.00	0.41	6	1.07	0.05	5
450.0	...	...	...	...	...	...	...	...	...	8.92	0.17	6	1.03	0.05	5
444.3	8.68	0.58	7	1.26	0.07	6	4.11	0.25	6	6.67	0.27	6	1.02	0.05	5
439.0	1.11	0.06	6	2.59	0.13	6	5.23	0.26	6	...	...	...	...	...	...
434.2	1.32	0.06	6	2.99	0.14	6	5.50	0.26	6	8.74	0.35	6	1.19	0.05	5
430.0	...	...	...	...	...	...	...	...	...	1.40	0.07	5	2.11	0.08	5
424.3	2.12	0.08	6	3.75	0.15	6	7.31	0.29	6	1.12	0.04	5	1.54	0.08	5
414.4	2.85	0.12	6	4.75	0.19	6	6.78	0.35	6	1.32	0.05	5	1.78	0.10	5
404.5	3.51	0.11	6	5.46	0.22	6	1.02	0.04	5	1.56	0.06	5	2.09	0.08	5
400.0	...	...	...	6.25	0.25	6	1.09	0.04	5	...	...	...	2.36	0.09	5
394.7	4.16	0.17	6	6.32	0.26	6	1.15	0.05	5	1.75	0.07	5	2.22	0.09	5
385.7	4.55	0.18	6	7.09	0.28	6	1.21	0.05	5	1.86	0.07	5	2.54	0.14	5
374.9	4.76	0.19	6	6.97	0.28	6	1.31	0.05	5	1.94	0.08	5	2.72	0.11	5
365.0	4.56	0.18	6	7.28	0.29	6	1.32	0.05	5	2.08	0.08	5	2.69	0.10	5
360.0	4.50	0.18	6	6.61	0.28	6	1.32	0.05	5	...	...	...	2.88	0.11	5
355.2	4.35	0.17	6	6.97	0.28	6	1.36	0.05	5	2.08	0.08	5	2.69	0.11	5
345.3	3.68	0.15	6	6.51	0.26	6	1.35	0.05	5	1.85	0.07	5	2.72	0.11	5
335.4	2.90	0.12	6	5.91	0.24	6	1.29	0.05	5	1.87	0.03	5	2.48	0.10	5
325.5	2.59	0.10	6	5.23	0.21	6	1.05	0.04	5	1.61	0.07	5	2.48	0.11	5
320.0	...	...	...	...	...	...	...	...	...	2.35	0.09	5	3.34	0.14	5
315.7	2.16	0.10	6	4.43	0.18	6	9.41	0.38	6	1.47	0.06	5	2.26	0.09	5
305.8	1.84	0.09	6	3.79	0.15	6	8.61	0.32	6	1.23	0.05	5	2.03	0.08	5
300.0	...	...	...	...	...	...	...	...	...	1.97	0.08	5	3.27	0.13	5
295.9	1.55	0.09	6	3.38	0.14	6	6.77	0.29	6	9.97	0.40	6	1.80	0.07	5
295.9	1.50	0.09	6	2.96	0.14	6	6.64	0.31	6	9.73	0.39	6	1.72	0.07	5
276.2	1.14	0.08	6	2.64	0.13	6	6.03	0.32	6	8.35	0.41	6	1.50	0.07	5
266.3	1.08	0.08	6	2.61	0.14	6	5.32	0.33	6	8.57	0.13	6	1.31	0.08	5
260.0	...	...	...	...	...	...	...	...	...	1.39	0.08	5	1.95	0.13	5
256.4	1.28	0.09	6	2.43	0.15	6	5.71	0.35	6	8.33	0.45	6	1.27	0.08	5
246.6	1.20	0.09	6	2.55	0.16	6	5.47	0.36	6	8.55	0.18	6	1.39	0.09	5
236.7	1.15	0.10	6	2.54	0.16	6	5.18	0.38	6	8.71	0.51	6	1.31	0.09	5
226.8	1.27	0.11	6	2.88	0.19	6	5.62	0.12	6	8.72	0.51	6	1.29	0.10	5
216.9	1.43	0.14	6	2.91	0.21	6	6.35	0.49	6	9.81	0.56	6	1.34	0.10	5
207.0	1.66	0.16	6	2.91	0.21	6	6.59	0.52	6	1.02	0.06	5	1.13	0.11	5
197.2	1.78	0.17	6	3.42	0.24	6	7.01	0.59	6	...	...	...	1.59	0.12	5

ELEM. SYM.	A	Z
Mg	24	12
METHOD	REF. NO.	
75 Be 1		hmrg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, G	LFT	9- 11	C	29	SCD-D		125
		(9.83-10.73)		(28.7)			

TABLE II. Integrated scattering cross sections  $I_s$  and derived  $\gamma$ -decay widths.

Transition (Energy in MeV)	Titze <sup>a</sup> $\Gamma_\gamma^0$ (eV)	Fagg <sup>b</sup> $\Gamma_\gamma^0$ (eV)	$\Gamma_\gamma^0$ (eV)	This work $\Gamma_\gamma^1$ (eV)	$I_s$ (MeV mb)
10.71 → g.s.	$15.9 \pm 2.4$	$17.6^{+3.5}_{-3.0}$	$17.8^{+6.9}_{-5.6}$	$1.45^{+0.64}_{-0.44}$	
10.71 → 1.38				$4.2^{+1.3}_{-1.6}$	$0.33^{+0.17}_{-0.12}$
9.97 → g.s.	$4.50 \pm 0.73$		$6.2^{+2.1}_{-2.2}$	$0.48^{+0.23}_{-0.16}$	
9.97 → 1.38		$\Sigma =$ $7.6^{+1.5}_{-1.4}$		$2.8^{+1.2}_{-1.0}$	$0.22^{+0.11}_{-0.08}$
9.83 → g.s.	$1.05 \pm 0.26$		$1.7^{+1.0}_{-0.7}$	$0.16^{+0.08}_{-0.06}$	
9.83 → 1.38				$0.5^{+0.5}_{-0.4}$	$0.045^{+0.043}_{-0.036}$

<sup>a</sup> Reference 2.

<sup>b</sup> Reference 3.

<sup>2</sup>O. Titze, Z. Phys. 220, 66 (1969).

<sup>3</sup>L.W. Fagg et al., Phys. Rev. C1, 1137 (1970).



METHOD			REF. NO.			
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE	RANGE	TYPE	RANGE
A, G	ABX	11- 26	D	3- 20	NAI-D	DST

SEE ANALYSIS 79KU5

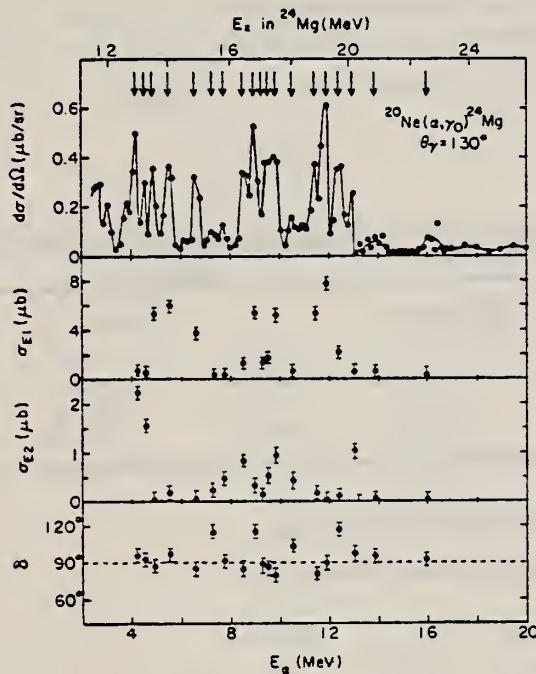
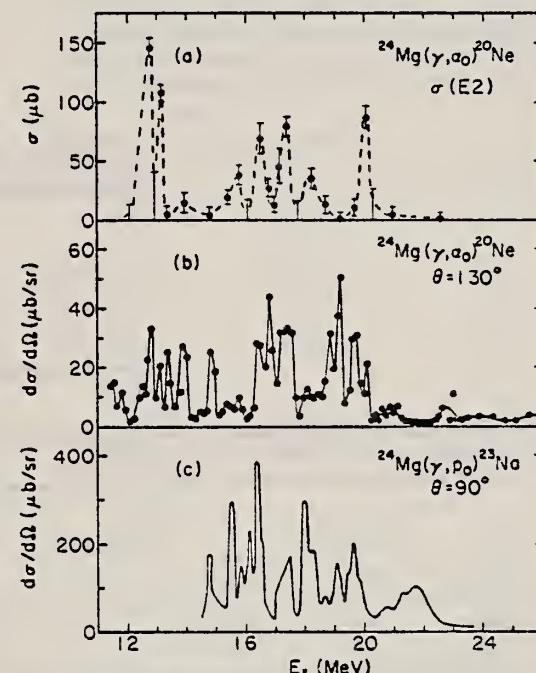


FIG. 2. Top: excitation function at  $\theta = 130^\circ$  for the reaction  $^{20}\text{Ne}(\alpha, \gamma)^{24}\text{Mg}$ . The arrows indicate energies at which angular distributions were studied. Middle: the extracted  $E_1$  and  $E_2$  total cross sections for the  $(\alpha, \gamma_0)$  reaction. Bottom: the  $E_2$  phase  $\delta$ , relative to the  $E_1$  phase, which is arbitrarily set to zero.



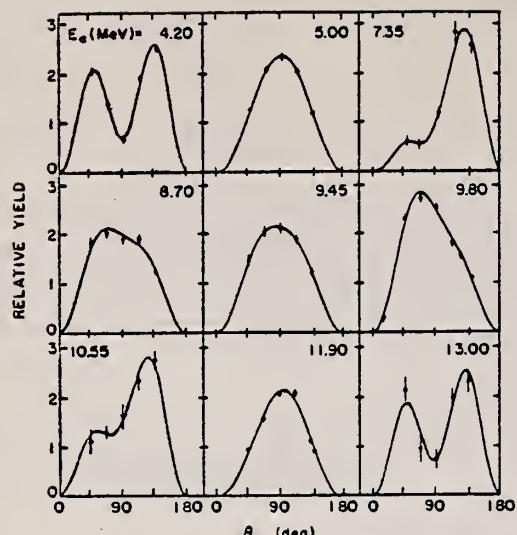


FIG. 3. Typical angular distributions for the reaction  $^{20}\text{Ne}(\alpha, \gamma)^{24}\text{Mg}$ . Note the almost pure  $E1$  character of the distributions at  $E_\alpha = 5.00$  and  $11.90$  MeV in marked contrast to the predominantly  $E2$  character at  $4.20$  and  $13.00$  MeV. The solid lines are fits in terms of Eq. (3).

TABLE I. The averaged absolute cross sections  $\bar{\sigma}(\alpha, \gamma_0)$  and  $\bar{\sigma}(\alpha, \gamma_1)$  for the reactions  $^{20}\text{Ne}(\alpha, \gamma)^{24}\text{Mg}$  and  $^{22}\text{Ne}(\alpha, \gamma)^{25}\text{Mg}$ .

$\Delta E_x$ (MeV)	$^{20}\text{Ne}(\alpha, \gamma)^{24}\text{Mg}$ $\bar{\sigma}(\alpha, \gamma_0)$ <sup>a</sup> ( $\mu\text{b}$ )	$^{20}\text{Ne}(\alpha, \gamma)^{24}\text{Mg}$ $\bar{\sigma}(\alpha, \gamma_1)$ <sup>b</sup> ( $\mu\text{b}$ )	$^{22}\text{Ne}(\alpha, \gamma)^{25}\text{Mg}$ $\bar{\sigma}(\alpha, \gamma_0)$ <sup>a</sup> ( $\mu\text{b}$ )	$^{22}\text{Ne}(\alpha, \gamma)^{25}\text{Mg}$ $\bar{\sigma}(\alpha, \gamma_1)$ <sup>b</sup> ( $\mu\text{b}$ )
11.4–14.4	3.2	3.9	...	...
14.4–17.8	3.1	4.8	9.2	8.6
17.8–20.2	3.6	9.6	3.0	4.5
20.2–23.8	0.6	1.8	0.9	2.8
23.8–26.0	0.4	0.6	...	...

<sup>a</sup> Angular distribution assumed to be of the form  $W(\theta) = \sin^2 \theta$ .

<sup>b</sup> Angular distribution assumed to be isotropic.

TABLE II. Summary of  $E2$  strengths in  $^{24,26}\text{Mg}(\gamma, \alpha_0)$  (see text) given in percent of the  $E2$  sum rule [Eq. (5)].

Nucleus	$\Delta E$ (MeV)	$\int \sigma(E2)/E^2 dE$ (%)	$\Delta E$ (MeV)	$\int \sigma_{\text{CN}}(E2)/E^2 dE$ (%)
$^{24}\text{Mg}$	12.0–22.5	$11.8 \pm 1.0$	0–22.5	$120 \pm 30$
$^{26}\text{Mg}$	15.0–21.4	$6.0 \pm 2.0$	0–21.4	$290 \pm 80$

TABLE III. A comparison of the integrated  $E1$  strengths found in various reactions in the GDR's of  $^{24}\text{Mg}$  and  $^{26}\text{Mg}$ . The strengths are given in percent of the  $E1$  sum rule [Eq. (4)].

Nucleus	$(\gamma, \alpha)$		$(\gamma, p_0)$ <sup>a</sup>		$(\gamma, n)$ <sup>b</sup>		$(e, e')$ <sup>c</sup>	
	$\Delta E$ (MeV)	$\int \sigma(E1)dE$ (%)	$\Delta E$ (MeV)	$\int \sigma(E1)dE$ (%)	$\Delta E$ (MeV)	$\int \sigma(E1)dE$ (%)	$\Delta E$ (MeV)	$\int \sigma(E1)dE$ (%)
$^{24}\text{Mg}$	14.6–20.6	0.33	15.5–23.0	3.3	16.5–28.0	14.0	16.0–22.0	30.0
$^{26}\text{Mg}$	14.8–21.0	0.70	...	...	11.0–29.0	58.0	14.5–28.0	48.0

<sup>a</sup> Reference 14.

<sup>b</sup> Reference 15.

<sup>c</sup> References 19 and 27.

- 14 R.C. Bearse et al., Nucl. Phys. A116, 682 (1968).
- 15 S.C. Fultz et al., Phys. Rev. C4, 149 (1971).
- 19 O. Titze et al., Phys. Lett. 24B, 169 (1967); A. Goldmann, Z. Phys. 234, 144 (1970).
- 27 O. Titze et al., Phys. Lett. 31B, 565 (1970).

ELEM. SYM.	A	Z
Mg	24	12

METHOD	REF. NO.					
	76 Ba 2					
	egf					
REACTION	RESULT					
EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE			
	TYPE	RANGE	TYPE	RANGE		
G,P	SPC	13- 30	C	18- 30	TEL-D	90
G,PG	ABY	12- 30	C	18- 30	SCD-D	125
G,NG	ABY	17- 30	C	18- 30	SCD-D	125
G,A	ABX	18- 22	C	30	TEL-D	90

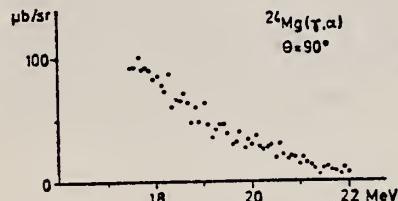


Fig. 2. The  $^{24}\text{Mg}(\gamma, \alpha)$  differential cross section obtained from the 30.0 MeV  $\alpha$ -particle spectrum.

TABLE I  
 Structures in the  $^{24}\text{Mg}(\gamma, p)$  spectra \*)

Run (MeV)	18	19.5	21	23	30
Peaks at (MeV)					
2.63	2.76	2.82			2.8
3.00	2.92	3.03	2.92	3.02	
3.83		3.78	3.88	3.96	
4.26	4.18	4.07	4.10	4.20	
	4.63	4.65	4.75	4.73	
4.80		5.11		5.13	
5.35		5.43			
5.55	5.58	5.66			
5.76			5.8	5.73	
			5.96		
	6.32	6.26	6.43	6.42	
		6.84	6.86	6.80	
			7.06	7.03	
			7.70	7.66	
			7.98	7.95	
			8.4	8.4	
			8.7	8.6	
			8.9	8.9	
			10.4	10.6	
				10.9	
				12.5	

\*) Peak energies are corrected for energy loss in the target and for recoil energy, assuming direct  $(\gamma, p)$  reactions.

(over)

TABLE 2

Results of the  $^{24}\text{Mg}(\gamma, xy')$  experiment, giving the "bremsstrahlung-weighted" integrated cross sections in MeV · mb for the population of excited residual nuclear states

	Bremsstrahlung endpoint energy (MeV)				
	18.0	19.5	21.0	23.0	30.5
<b>(a) <math>^{23}\text{Na}</math> states</b>					
g.s. $\frac{1}{2}^+$ *)	0.67	1.02	1.52	2.07	<b>2.59</b>
440 keV, $\frac{1}{2}^+$	?	?	?	?	?
2076 keV, $\frac{1}{2}^+$	<1.25	<2.24	<2.74	<5.49	<8.90
2391 keV, $\frac{1}{2}^+$	0.99	2.73	4.68	7.45	<b>10.56</b>
2640 keV, $\frac{1}{2}^-$	0.80	1.41	2.27	4.52	8.02
2704 keV, $\frac{3}{2}^+$				<1.25	<2.80
2982 keV, $\frac{3}{2}^+$		0.85	1.77	3.13	<b>5.73</b>
3678 keV, $\frac{3}{2}^-$		0.65	1.34	2.72	<b>4.44</b>
3848 keV, $\frac{5}{2}^-$				0.82	2.03
3915 keV, $\frac{5}{2}^+$		0.57	0.94	2.27	6.27
4432 keV, $\frac{5}{2}^+$		0.94	1.78	3.22	<b>6.53</b>
5380 keV, $(\frac{5}{2}, \frac{3}{2})^+$			0.7	1.31	<b>1.89</b>
5967 keV, $(\frac{5}{2}, \frac{3}{2})^-$		0.3	0.51	1.81	<3.5
<b>(b) <math>^{23}\text{Mg}</math> states</b>					
g.s. $\frac{3}{2}^+$	?	?	?	?	?
451 keV, $\frac{3}{2}^+$	?	?	?	?	?
2051 keV, $\frac{3}{2}^+$					0.85
2359 keV, $\frac{3}{2}^+$				1.46	<b>2.13</b>
2715 keV, $\frac{3}{2}^+$				<1.18	<1.79
2771 keV, $\frac{3}{2}^-$				0.93	3.05
4356 keV, $\frac{3}{2}^+$				0.3	0.55
<b>(c) <math>^{22}\text{Ne}</math> states</b>					
1275 keV, $2^+$					<b>1.17</b>
<b>(d) <math>^{20}\text{Ne}</math> states</b>					
1634 keV, $2^+$	<1.25	<2.24	<2.74	<5.49	<8.9
Sum of observed $(\gamma, p)$ excited states cross sections	1.79	7.18	13.99	28.50	<b>51.77</b>
Sum of observed $(\gamma, n)$ excited states cross sections				3.87	<b>8.37</b>
Total $(\gamma, n)$ yield <sup>b)</sup>	0.57	3.16	6.91	11.97	<b>21.41</b>
Total photoabsorption yield <sup>c)</sup>	7.46	16.23	32.42	52.62	<b>104.55</b>

The bremsstrahlung spectra are normalized at 10.71 MeV.

\*) Calculated from the data of ref. <sup>14</sup>).

<sup>b)</sup> Calculated from the data of ref. <sup>2</sup>).

<sup>c)</sup> Calculated from the data of ref. <sup>22</sup>).

<sup>14</sup> S.C. Fultz et al., Phys. Rev. C4, 149 (1971); R.A. Alvarez et al., Phys. Rev. C4, 1673 (1971).

<sup>2</sup> R.C. Bearse et al., Nucl. Phys. A116, 682 (1968).

<sup>22</sup> B.S. Dolbilkin et al., Bull. Acad. Sci. USSR 30, 354 (1966).

REF.

H. Zarek, B. O. Pich, T. E. Drake, D. J. Rowe, W. Bertozzi,  
 C. Creswell, A. Hirsch, M. V. Hynes, S. Kowalski, B. Norum,  
 F. N. Rad, C. P. Sargent, C. F. Williamson and R. A. Lindgren  
 Phys. Rev. Lett. 38, 750 (1977)

ELEM. SYM. A

Z

Mg 24

12

METHOD

REF. NO.

77 Za 2

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,E/	FMF	15	D	108-260	MAG-D		DST

The unique high-resolution and high-energy features of the electron-scattering facility at the MIT-Bates Accelerator were used to locate a dominant narrow resonance at  $15.045 \pm 0.035$  MeV in  $^{24}\text{Mg}$ . A spin-parity assignment of  $6^-$  and an isospin  $T=1$  assignment were made. The  $M6$  form factor was measured and compared to the prediction of a theoretical calculation which uses the open-shell random-phase approximation on a shell-model ground state for  $^{24}\text{Mg}$ .

15.045 MeV

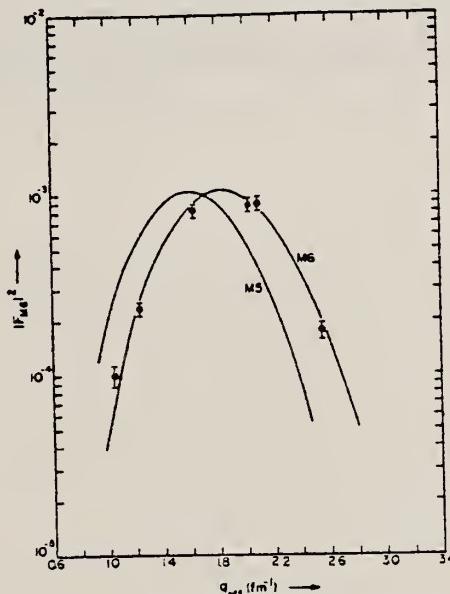


FIG. 3. The form factor  $|F_{M6}(Q)|^2$  for the  $6^-, T=1$  resonance at  $15.045 \pm 0.035$  MeV in  $^{24}\text{Mg}$ . The open-shell random-phase approximation calculation for  $M6$  is shown as a solid line. An  $M5$  curve (see text) is added for comparison purposes.



REF.	L.K. Fifield, M.J. Hurst, T.J.M. Symons, F. Watt, C.H. Zimmerman, and K.W. Allen Nuclear Physics A309, 77 (1978)	ELEM. SYM.	A	Z
METHOD		Mg	24	12

METHOD				REF. NO.	
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE	RANGE	
A,G	LFT	12-15 (12.00-14.15)	C	3-6 (3.05-5.8)	SCD-D
					DST

### 8 LEVELS STUDIED

**Abstract:** The  $^{20}\text{Ne}(\alpha, \gamma)^{24}\text{Mg}$  reaction has been used to measure radiative decay rates for known high spin levels at 12.86( $6^+$ ), 13.44( $6^+$ ) and 14.15( $8^+$ ) MeV in  $^{24}\text{Mg}$ , and for previously unidentified levels at 12.00, 13.04 and 14.08 MeV. Gamma-ray angular distributions indicate that the 12.00 and 14.08 MeV levels are probably  $6^+$  levels, while the 13.04 MeV level is the lowest  $0^+ T = 1$  state. A new level at 11.005 MeV, populated in the radiative decay of the 14.08 MeV level, is most likely the lowest  $5^+ T = 1$  state in  $^{24}\text{Mg}$ . Alpha-particle widths have also been measured for several of these levels and for the known  $6^+$  level at 13.85 MeV using the  $^{20}\text{Ne}(\alpha, \alpha'\gamma)^{20}\text{Ne}$  reaction and previously determined branching ratios. The results for both radiative and particle decay widths are compared with recent shell-model calculations performed within a full (sd) $^8$  basis.

E NUCLEAR REACTIONS  $^{20}\text{Ne}(\alpha, \gamma), ^{20}\text{Ne}(\alpha, \alpha'\gamma), E = 3.0\text{--}6.0 \text{ MeV}$ ; measured  $\sigma(E_\alpha, E_\gamma, \theta)$ .  
 $^{24}\text{Mg}$  deduced levels,  $J$ ,  $\pi$ ,  $T$ ,  $\gamma$ -ray branching ratios, radiative widths,  $\alpha$ -particle widths.  
Windowless gas target.

TABLE 4  
Alpha particle widths of 6<sup>+</sup> and 8<sup>+</sup> levels in <sup>24</sup>Mg

Level	$E_\alpha$ (MeV)	$\omega_{\alpha}^2 \cdot \mu$ (eV)	$\Gamma_{\alpha}/\Gamma^b$	Ground-state transitions			Transitions to 1.63 MeV state		
				$\Gamma_{\alpha}$ (eV)	$g_{\alpha}^2 \cdot \mu$	$A_{NL}^{2+4}$	$\Gamma_{\alpha}$ (eV)	$g_{\alpha}^2 \cdot \mu$	$A_{NL}^{2+4}$
6 <sub>3</sub>	12.00	<sup>b</sup>		> 0.022	> 7.6 × 10 <sup>-3</sup>	5.1 × 10 <sup>-3</sup>	0.54 ± 0.08	0.00 ± 0.02	3.5 × 10 <sup>-3</sup>
6 <sub>4</sub>	12.86	2.4 ± 0.3	0.35 ± 0.04	0.33 ± 0.04	(4.0 ± 0.5) × 10 <sup>-3</sup>	8.6 × 10 <sup>-3</sup>	4.9 ± 1.7	0.03 ± 0.01	2.5 × 10 <sup>-3</sup>
6 <sub>5</sub>	13.44	15 ± 5	0.23 ± 0.03	1.6 ± 0.6	(3.5 ± 1.3) × 10 <sup>-3</sup>	3.5 × 10 <sup>-3</sup>	100 ± 40	0.13 ± 0.05	1.1 × 10 <sup>-4</sup>
6 <sub>6</sub>	13.85	40 ± 10	0.03 ± 0.01	3.0 ± 1.3	(2.6 ± 1.1) × 10 <sup>-3</sup>	2.2 × 10 <sup>-3</sup>	105 ± 25 <sup>c</sup>	0.06 ± 0.014	
6 <sub>7</sub>	14.08	1160 ± 165	> 0.7 <sup>d</sup>	250 < $r_{\alpha} < 0.000$	0.13 < $g_{\alpha}^2 < 0.51$	<sup>e</sup>			
8 <sub>1</sub>	- 11.86			< 1.2 × 10 <sup>-2</sup>	< 3.4 × 10 <sup>-3</sup>	2.7 × 10 <sup>-3</sup>			
8 <sub>2</sub>	- 13.21			< 2.2 × 10 <sup>-3</sup>	< 1.6 × 10 <sup>-3</sup>	2.8 × 10 <sup>-3</sup>			
8 <sub>3</sub>	14.15		0.22 ± 0.04	0.075 ± 0.016 <sup>f</sup>	(3.7 ± 0.8) × 10 <sup>-3</sup>	8.0 × 10 <sup>-3</sup>	0.18 ± 0.05 <sup>g</sup>	(6.9 ± 1.9) × 10 <sup>-3</sup>	2.5 × 10 <sup>-2</sup>

<sup>a</sup>  $\omega_{\alpha}^2 = (2J+1)\Gamma_{\alpha}^2 F_{\alpha}^2 / \Gamma^2$ .

<sup>b</sup> Derived from the present work and from  $\alpha$ -particle branching ratios in ref. <sup>9</sup>. Errors were estimated from data in ref. <sup>9</sup>.

<sup>c</sup>  $g_{\alpha}^2 = \Gamma_{\alpha} / (2\hbar^2 P_L \mu R^2)$ , where  $\mu$  is the reduced mass of the <sup>20</sup>Ne +  $\alpha$  system,  $R = r_0 (20^{1/3} + 4^{1/3})$  fm,  $P_L(kR)$  is the penetrability factor for relative orbital angular momentum  $L$  and wave number  $k$ .

<sup>d</sup> Ref. <sup>11</sup>.

<sup>e</sup> The 12.00 MeV level was not observed as a <sup>20</sup>Ne( $\alpha$ )<sup>20</sup>Ne\* resonance.

<sup>f</sup> See text.

<sup>g</sup> Calculations are not available for this level.

<sup>h</sup> Using  $\Gamma_{\alpha}/\Gamma = 0.85 \pm 0.15$ .

<sup>i</sup> Ref. <sup>9</sup>.

<sup>j</sup> Derived from known  $\alpha$ -particle and  $\gamma$ -ray branching ratios <sup>9</sup> using our measured value of  $\Gamma_{\alpha}$ .

**Alpha-particle widths.** Alpha-particle widths of 6<sup>+</sup> and 8<sup>+</sup> levels in <sup>24</sup>Mg are summarised in table 4. With the exception of the 11.86 and 13.21 MeV 8<sup>+</sup> levels, all the values are from the present work using branching ratios from ref. <sup>9</sup> where appropriate. The spectroscopic factors,  $g_{\alpha}^2$ , were derived from the measured widths using a radius parameter  $r_0$  of 1.2 fm; increasing  $r_0$  to 1.4 fm decreases  $g_{\alpha}^2$  by a factor between 4 and 10 depending on the transition. Theoretical calculations by Kelvin *et al.* <sup>11</sup>), using wave functions generated with the CWC interaction, are tabulated in the final column. The quantity  $A_{NL}^{2+4}$  is as defined by Ichimura *et al.* <sup>22</sup>), and when calculated with harmonic oscillator wave functions should be approximately equal to  $g_{\alpha}^2$ . The  $N$  and  $L$  are the oscillator quantum numbers for the c.m. of the  $\alpha$ -particle, where  $2N+L=8$  if the same oscillator length parameters are used for the internal structure of the  $\alpha$ -particle and for the sd shell wave functions. In deriving  $g_{\alpha}^2$  for the 14.08 MeV level, we have assumed a conservative upper limit of 30 % on an  $\alpha$ -particle branch to the 1.63 MeV level in <sup>20</sup>Ne, and have used  $\Gamma_{\alpha}/\Gamma = 0.85 \pm 0.15$  in deriving  $g_{\alpha}^2$ .

Ref. 9 -- L.K. Fifield, R.W. Zurmühle and D.P. Balamuth, Phys. Rev. C8, (1973) 2217

Ref. 11 - D. Kelvin, A. Watt and R.R. Whitehead, to be published

Ref. 22 - M. Ichimura, A. Arima, E.C. Halbert and T. Terasawa, Nucl. Phys. A204, (1973) 225

ELEM. SYM.	A	Z
Mg	24	12

METHOD	REF. NO.			
	78 Ma 10			
	hg			
REACTION	RESULT			
G,PN	ABY			
EXCITATION ENERGY	SOURCE			
	TYPE	RANGE	DETECTOR	ANGLE
26-68	C	30-68	ACT-I	4PI

Analysis is made of reactions interfering with photon activation analysis procedures.

The activation yield curves have been presented for a number of photonuclear reactions in the energy range from 30 to 68 MeV, in order to evaluate quantitatively the interferences due to competing reactions in multielement photon activation analysis. The general features of the yields as functions of both target mass number and excitation energy were elucidated from the data obtained, discussion being given on the results in terms of the reaction mechanism.

Simultaneous neutron activation due to appreciable neutron production from the converter and surrounding materials has also been studied, and, finally, the magnitudes of interferences in real multielement analysis were given in the form of their energy dependences.

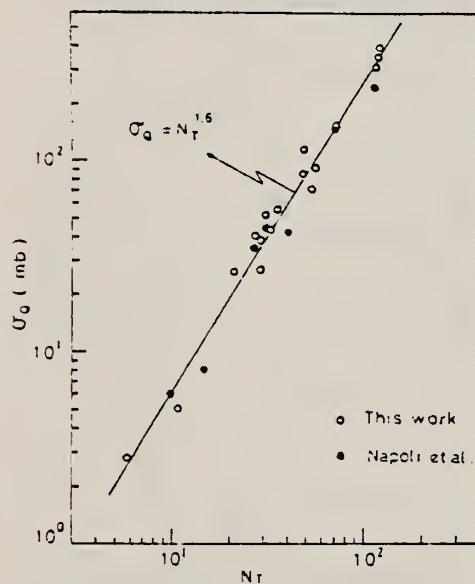


Fig. 2. Yield per equivalent quanta versus target neutron number.

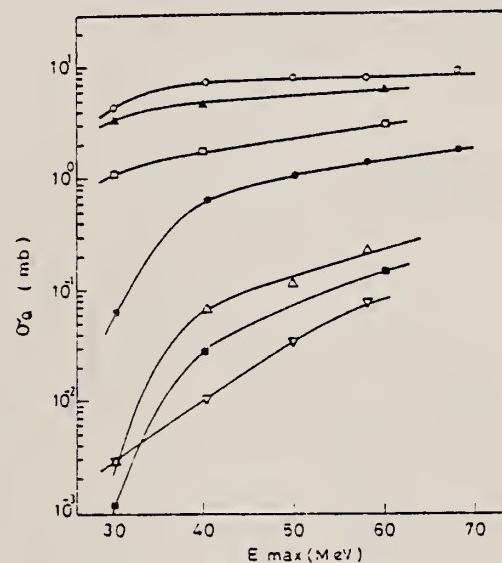


Fig. 3. Activation yield curves for the reactions on C, Na, Mg and Al.  
 □  $^{12}\text{C}(\text{p}, \text{n})^{11}\text{C}$ , ■  $^{12}\text{C}(\text{p}, \gamma)^7\text{Be}$ , ▲  $^{23}\text{Na}(\text{p}, \text{n})^{22}\text{Na}$ ,  
 ○  $^{25}\text{Mg}(\text{p}, \gamma)^{24}\text{Na}$ , ●  $^{24}\text{Mg}(\text{p}, \text{n})^{22}\text{Na}$ , Δ  $^{27}\text{Al}(\text{p}, \text{n})^{22}\text{Na}$ ,  
 △  $^{27}\text{Al}(\gamma)^{24}\text{Na}$ .

(over)

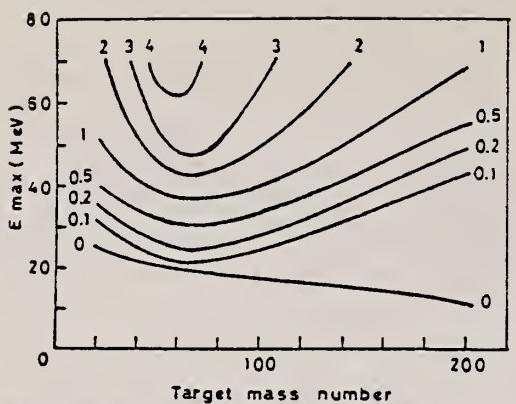


Fig. 11. Yields of the ( $\gamma$ , pn) reactions as a function of bremsstrahlung maximum energy and target mass number. The numerical values in the figure are yields per equivalent quanta in mb.

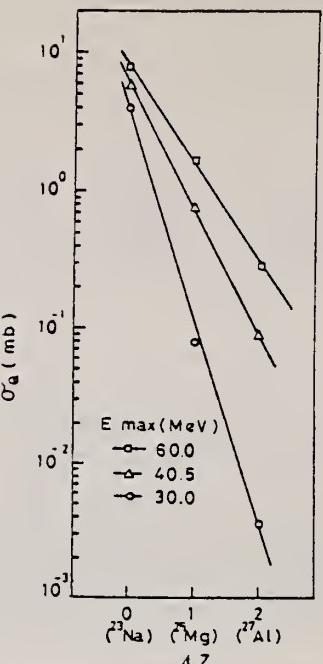


Fig. 12. The reaction yields leading to  $^{22}\text{Na}$  as a function of difference in atomic number between target and product nuclides.

REF.	A.M. Sandorfi and A.M. Nathan Phys. Rev. Lett. <u>40</u> , 1252 (1978)	ELEM. SYM.	A	Z		
		Mg	24	12		
METHOD	REF. NO.					
	78 Sa 3			rs		
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE	RANGE		TYPE
C12,G	ABX	18- 28	D	4- 14	NAI-D	45°

The yield curves of high-energy capture  $\gamma$  rays from  $^{12}\text{C}(^{12}\text{C}, \gamma_0)$  and  $^{12}\text{C}(^{12}\text{C}, \gamma_1)$  were measured at  $\theta_{\text{lab}} = 45^\circ$  from  $E_{\text{c.m.}} = 5.0$  to 11.0 MeV. A  $J'' = 2^+$  resonance, with a width (full width at half-maximum) of  $261 \pm 74$  keV and a peak cross section at  $45^\circ$  of  $44.3 \pm 4.5$  nb/sr, was observed in  $^{12}\text{C}(^{12}\text{C}, \gamma_0)$  at (21.98  $\pm$  0.03) MeV excitation in  $^{24}\text{Mg}$ . Several other resonant features were also observed in the  $\gamma$ -ray yields.

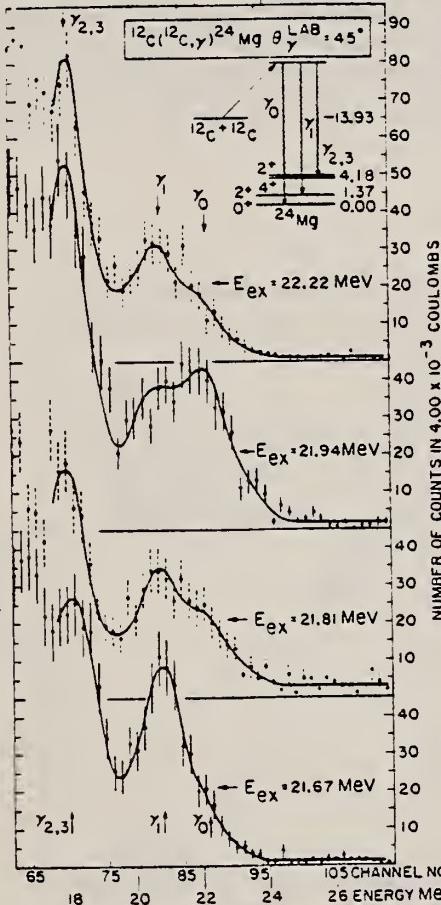


FIG. 1. The high-energy portion of the  $\gamma$ -ray spectra, taken at incident beam energies of 15.70, 15.98, 16.25, and 16.80 MeV with a 230-keV- (c.m.) thick target, are shown here. The spectra are labeled with the Doppler-shift-corrected excitation energies at the middle of the target and have been shifted linearly in channel number to compensate for the differences in energy. As displayed, all share a common energy scale with the data at 21.81 MeV excitation. The position of the centroids of  $\gamma_0$ ,  $\gamma_1$ , and  $\gamma_{2,3}$  are indicated. The variations of the Doppler shifts and of the peak widths are negligible for these spectra. The intensities of the high-energy  $\gamma$ -ray lines may thus be compared directly. The solid curves are three-peak fits to the data points (see text).

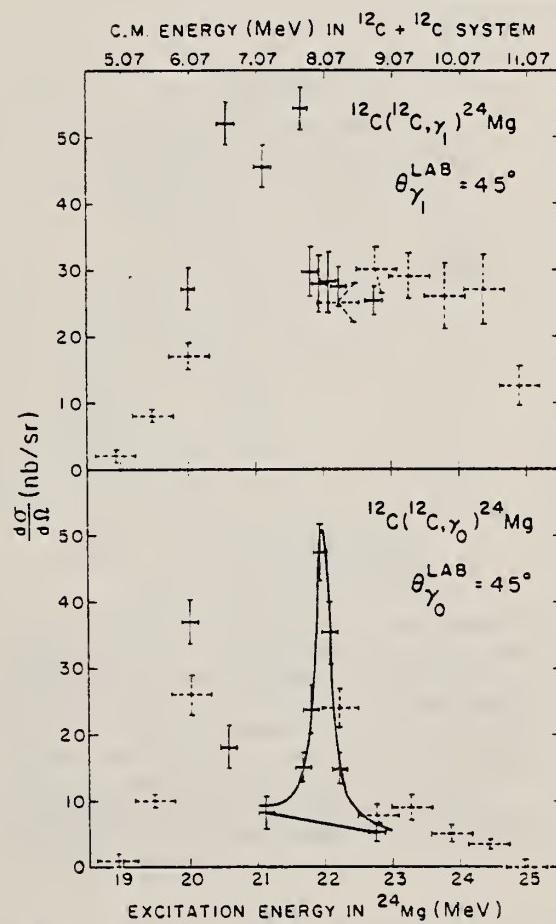


FIG. 2. The solid points on the excitation functions shown here were taken with a 74- $\mu\text{g}/\text{cm}^2$   $^{12}\text{C}$  (99.3%) target. The dashed data points were collected with a 280- $\mu\text{g}/\text{cm}^2$  natural carbon foil. The horizontal bars indicate the target thickness. The solid curve is a fit to the data assuming a single Breit-Wigner resonance (see text).



ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.

78 Sa 4

rs

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,F	ABX	20- 28	D	21- 32	TRK-D		DST

We report the electron-induced fission of  $^{24}\text{Mg}$  into two ground-state  $^{12}\text{C}$  nuclei following monopole excitation at energies between 20 and 22 MeV. The observed cross section exhausts at least  $(8 \pm 2)\%$  of the linear energy-weighted monopole sum rule  $S(E0)$  and may form a part of the giant monopole resonance. In addition, we have observed a peak in the  $\theta_{12\text{C}} = 45^\circ$  excitation function between 22.0 and 23.5 MeV with a width (full width at half-maximum)  $< 1$  MeV and a  $^{12}\text{C}$  angular distribution,  $\sin^2(2\theta_{\text{c.m.}})$ , indicating  $J'' = 2^+$ .

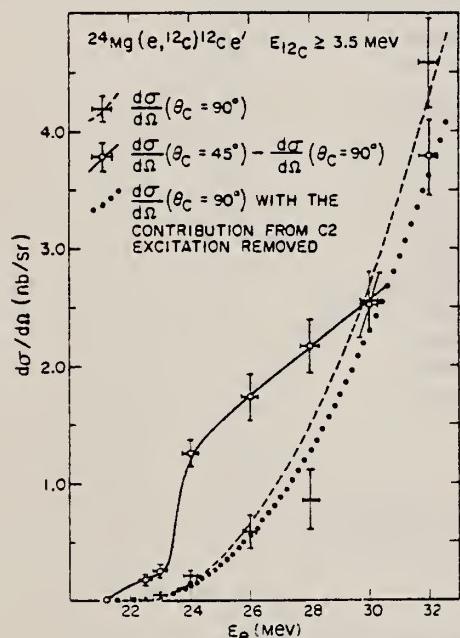


FIG. 1. Differential electrofission cross sections are shown here. The solid curve follows a form calculated assuming F2 excitation [Ref. 6, Eq. (14)]. The dashed and dotted curves are fits to the data assuming the quadratic energy dependence characteristic of "Coulomb" excitation (see text).

<sup>6</sup>G. Bishop, in "Nuclear Structure and Electromagnetic Interactions, Scottish Universities Summer School, Edinburgh, Scotland, 1964," edited by N. MacDonald (Oliver and Boyd, Edinburgh, Scotland, 1964).

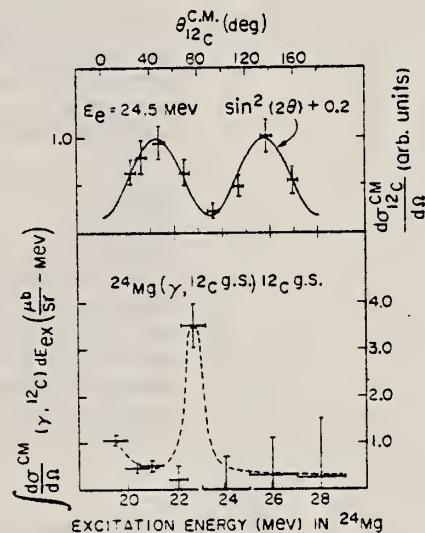


FIG. 2. The equivalent photofission cross section (bottom) was deduced from the data points on the solid curve of Fig. 1. The points shown here result from integrals over the regions of excitation energy denoted by the horizontal bars. Below 21 MeV, the cross sections are uncertain within a factor of 2, in addition to the errors shown (see text). The dashed curve is merely a guide to the eye. The  $^{12}\text{C}$  angular distribution (top) indicates a  $J'' = 2^+$  assignment to the peak centered at 22.7 MeV (bottom).

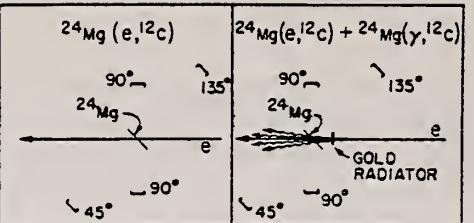


FIG. 3. The inability to excite  $0^+$  states with real photons was utilized, in the experiment shown here schematically, to verify the association of the  $90^\circ$  yield of Fig. 1 with monopole excitation (see text and Table D).

TABLE I.  $^{12}\text{C}$  production cross sections (nb/sr) with and without a photon converter. This data has not been corrected for  $^{16}\text{O}(e/\gamma, ^{12}\text{C})$  (10% of the yield at this electron energy).  $E_{^{12}\text{C}} \geq 3.5$  MeV.

$\theta(^{12}\text{C})$	45°	90°	135° <sup>a</sup>
Radiator out	$2.0 \pm 0.2$	$0.6 \pm 0.1$	$0.4 \pm 0.1$
Radiator in	$4.1 \pm 0.3$	$0.8 \pm 0.1$	$1.1 \pm 0.2$

<sup>a</sup>The 135° and 45° data differ because they are presented for a fixed detector development time (see Ref. 2). This results in an angle-dependent detector efficiency due to the varying kinematic shifts between laboratory and center-of-mass frames. This dependence was removed from the angular distribution measurements of Fig. 2 (see text).

<sup>2</sup>R. Fleischer, P. Price and R. Walker, "Nuclear Tracks in Solids (Univ. of California Press, Berkeley, 1975), pp. 136-137.

REF. H. Zarek, S. Yen, B.O. Pich, T.E.-Drake, C.F. Williamson, S  
 G. Kowalski, C.P. Sargent, W. Chung, B.H. Wildenthal,  
 M. Harvey and H.C. Lee  
 Phys. Lett. 80B, 26 (1978)

ELEM. SYM.	A	Z
Mg	24	12

METHOD

REF. NO.

78 Za 2

rs

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	FMF	4	D	1* 2	MAG-D		DST

The high-resolution electron scattering facility at the MIT-Bates accelerator was used to resolve the  $4_1^+$  4.12 MeV and  $2_2^+$  4.24 MeV levels in  $^{24}\text{Mg}$ . The respective E2 and E4 Coulomb form factors were measured and compared to form factors calculated theoretically; the  $4_1^+$  form factor exhibits a momentum-transfer dependence which strongly suggests that  $K$  is a good quantum number in  $^{24}\text{Mg}$ .

.8\*2.2 FM-1, SEE 81ZA1

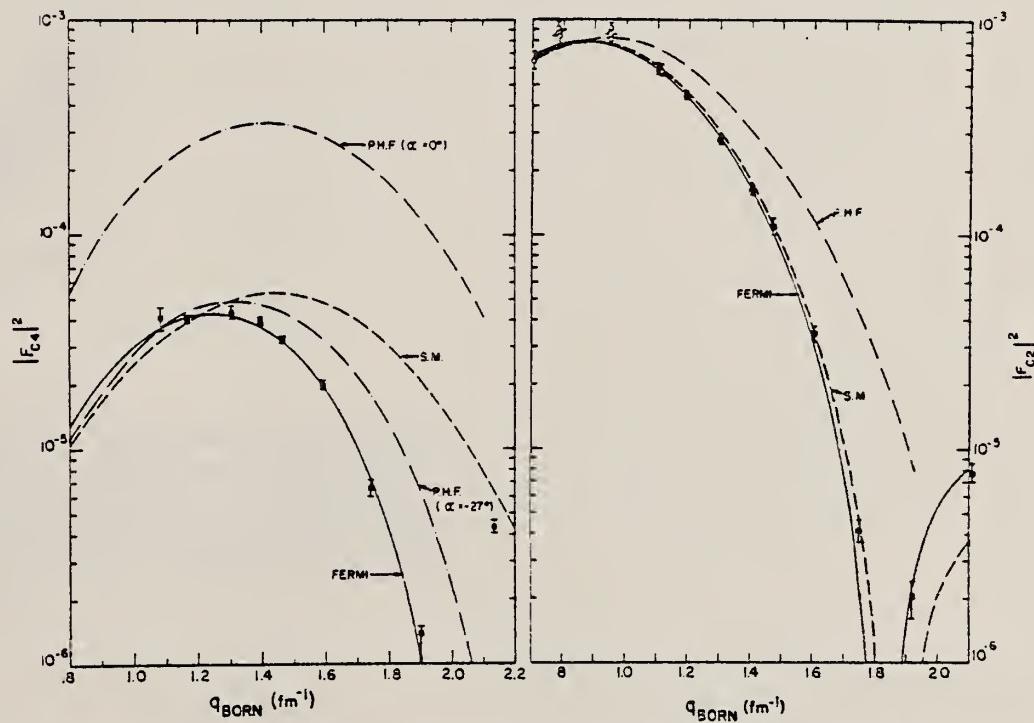


Fig. 2. The form factor for the  $4_1^+$  4.12 MeV level of  $^{24}\text{Mg}$  is on the left, and for the  $2_2^+$  4.24 MeV level on the right. The Fermi-density form factors are shown as a solid line, shell-model form factors as a dashed line and the PHF form factors as a dash-dot line.

over

**Table 1**  
Parameters for Fermi transition charge densities to the  $2^+$  and  
 $4^+$   $K = 0$  and 2 states in  $^{24}\text{Mg}$ .

$J^\pi$	$c(\text{fm})$	$r(\text{fm})$	$B(\text{E}\lambda\uparrow)$
$2_1^+$	2.77	2.35	$453 \pm 35 e^2 \text{fm}^4$
$2_2^+$	2.77	2.35	$27.4 \pm 3.0 e^2 \text{fm}^4$
$4_1^+$	3.625	1.85	$(2.0 \pm 0.3) \times 10^3 e^2 \text{fm}^8$
$4_2^+$	2.725	1.91	$(4.3 \pm 0.6) \times 10^4 e^2 \text{fm}^8$

ELEM. SYM.	A	Z
Mg	24	12
REF. NO.		
79 Eg 3	hg	

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,XP	RLY	12-250	C	130,250	MAG-D		DST

Experimental data are presented on the inclusive photoproduction of protons in the nuclei  $^{12}\text{C}$ ,  $^{24}\text{Mg}$ ,  $^{63}\text{Cu}$ ,  $^{118}\text{Sn}$ , and  $^{208}\text{Pb}$  irradiated by bremsstrahlung with maximum energies 0.13 and 0.25 GeV. The regions of angles 30–90° and of photoproton momenta 0.24–0.48 GeV/c were studied.

PACS numbers: 25.20. + y

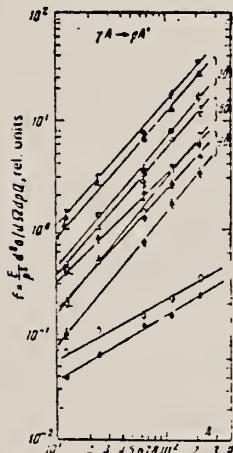


FIG. 5.  $A$ -dependence of the photoproton yield in reactions (2) and (3). Experimental points for  $E_{\gamma\max} = 0.25 \text{ GeV}$ : circles— $p_p = 0.29 \text{ GeV}/c$ ; triangles— $p_p = 0.34 \text{ GeV}/c$ , squares— $p_p = 0.40 \text{ GeV}/c$ ; half-open symbols—for  $\theta_p = 30^\circ$ , open symbols— $\theta_p = 60^\circ$ , solid symbols— $\theta_p = 90^\circ$ , for  $E_{\gamma\max} = 0.13 \text{ GeV}$ :  $\diamond$ — $p_p = 0.29 \text{ GeV}/c$ ,  $\theta_p = 30^\circ$ ;  $\oplus$ — $p_p = 0.34 \text{ GeV}/c$ ,  $\theta_p = 30^\circ$ . The lines have been drawn through the experimental points by the method of least squares.



REF. V.V. Varlamov, B.S. Ishkhanov, I.M. Kapitonov, Yu.I. Prokopchuk,  
V.I. Shvedunov  
Yad. Fiz. 30, 1185 (1979)  
Sov. J. Nucl. Phys. 30, 617 (1979)

ELEM. SYM.	A	z
Mg	24	12

METHOD

REF. NO.

79 Va 3

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,P	ABX	11-30	C	17-30	SCD-D		90

Photoproton spectra from  $^{24}\text{Mg}$  have been measured in a bremsstrahlung beam. The end-point energy was varied over the range 17–30 MeV with a 1-MeV step. From the photoproton spectra we calculated the distributions of the fraction of transitions to various states of the  $^{23}\text{Na}$  final nucleus and determined the partial cross sections corresponding to these transitions. The giant resonance of  $^{24}\text{Mg}$  is broken down into components associated with electric dipole transitions from the  $1d-2s$  outer shell and the  $1p$  inner shell. An estimate is given of the contribution of  $1p-1h$  configurations. The results are compared with theory.

PACS numbers: 25.20. + y

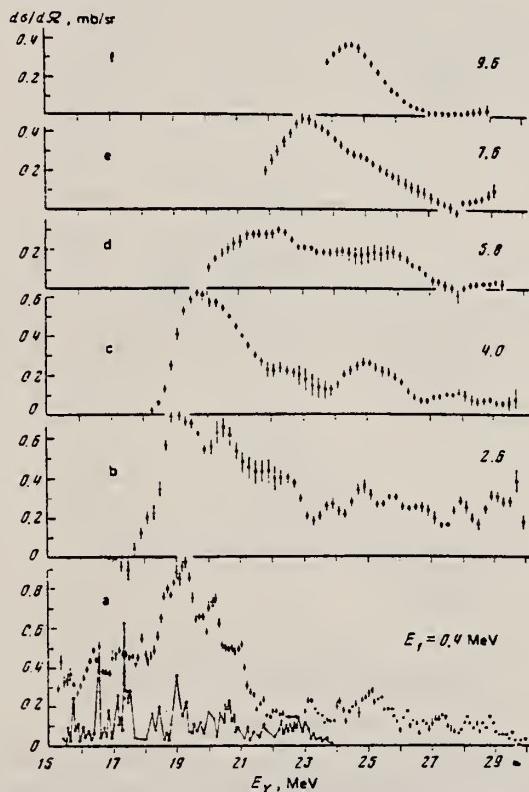


FIG. 3. Partial cross sections for the reaction  $^{24}\text{Mg}(\gamma, p)^{23}\text{Na}$  with formation of the final nucleus in groups of states with centers of gravity at 0.4, 2.6, 4.0, and 5.8, 7.6, and 9.6 MeV. In the lower figure we have also shown the cross section for the  $(\gamma, p)$  reaction from Ref. 11.

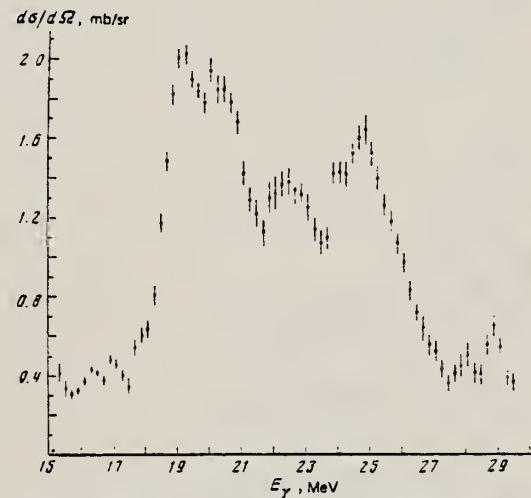


FIG. 4. Sum of the partial cross sections for the reaction  $^{24}\text{Mg}(\gamma, p)^{23}\text{Na}$ .

TABLE III. The main characteristics of electric dipole transitions which form the giant resonance of  $^{24}\text{Mg}$ .

Center of Gravity, MeV	Transitions from $1d-2s$ shell			Transitions from $1p$ shell			Difference of centers of gravity in an unaligned state, MeV	Location of aligned transitions, MeV	Contribution of $1p-1h$ configurations, %	Reference
	Energy, MeV	ip-1d, MeV	Fraction in integrated cross section	Center of Gravity, MeV	Energy, MeV	ip-1s, MeV	Fraction in integrated cross section			
17.3	5.0	0.47	27.0	4.8	0.33	9.7	23–28	100	[2]	
18.5	6.4	0.24	27.1	7.2	0.76	6.0	26–27	100	[2]	
22.1	3.8	0.37	21.1	6.3	0.13	-0.7	15–25	100	[4]	
21.6	6.3	0.65	23.6	5.1	0.35	2.0	19–21	75	Present work	

(over)

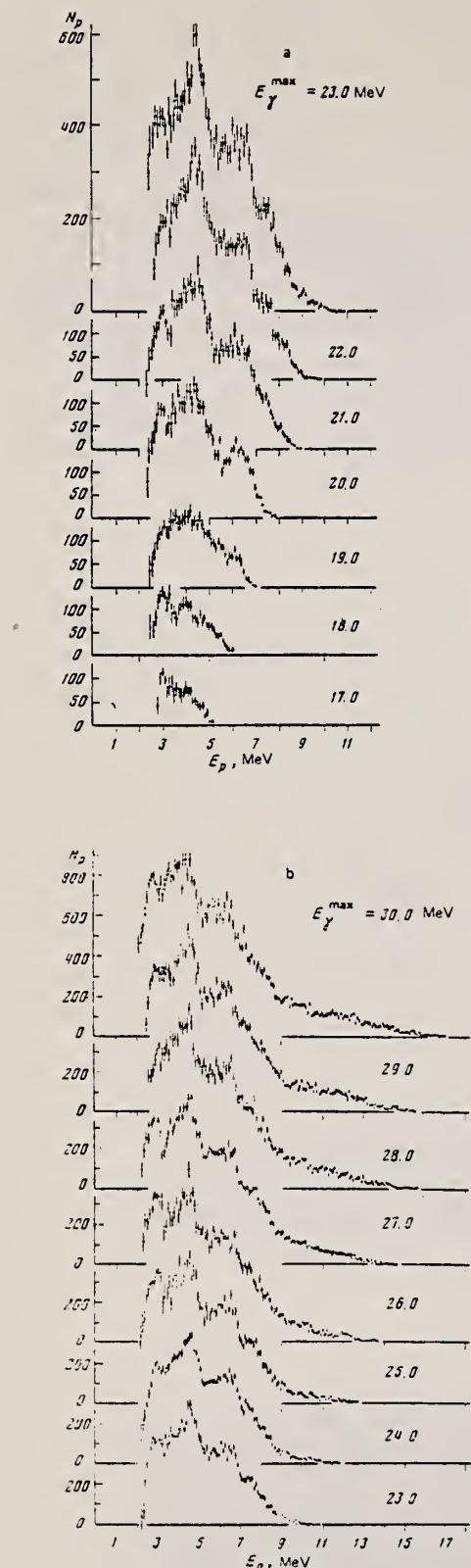


FIG. 1. Photoprovton spectra for  $E_{\gamma}^{\max} = 17-23$  MeV (a) and  $E_{\gamma}^{\max} = 23-30$  MeV (b).

ELEM. SYM.	A	Z
Mg	24	12

METHOD				REF. NO.	
				80 Sa 4	hg
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
E,F	ABX	13-29	D	26-40	TEL-D
					90

### FISS PROD COINC

Coincidence measurements of electrodisintegration products have been used to simultaneously study the  $^{12}\text{C} + ^{12}\text{C}$ ,  $^{16}\text{O} + ^8\text{Be}$ , and  $^{20}\text{Ne} + \alpha$  decay channels of  $^{24}\text{Mg}$ . Asymmetric fission into  $^{16}\text{O} + ^8\text{Be}$ , is concentrated between 18 and 28 MeV in  $^{24}\text{Mg}$  and exhibits resonances with cross sections ten times those of symmetric fission. There is little correlation among resonances in the three decay channels. The fission yields are not consistent with statistical decays from giant resonances, and suggest highly clustered states in  $^{24}\text{Mg}$ .

PACS numbers: 24.30.-v, 24.75.+i, 25.85.Ge

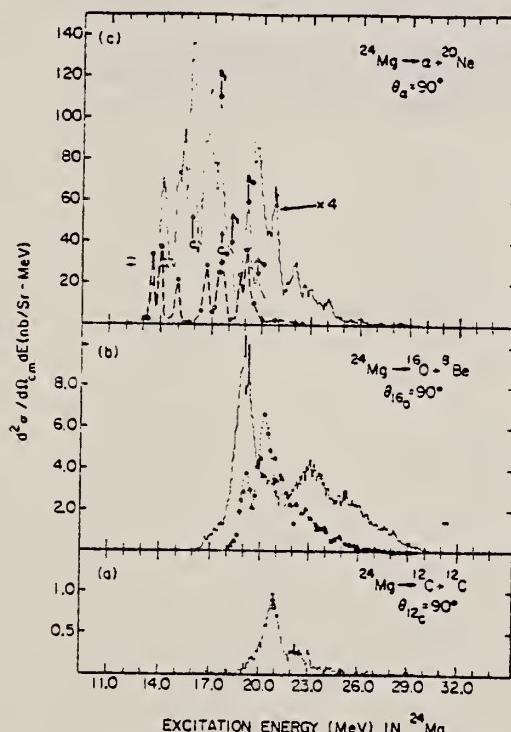


FIG. 3. The 90° cross sections (in nanobarn/steradian per megaelectronvolt excitation) for  $^{24}\text{Mg}(e, f_1 f_3)e'$  are histogrammed here for the main decay channels of Fig. 1. A vertical bar on each spectrum at  $E_{\text{ex}} = 20.8$  MeV indicates the level of statistical uncertainty. The  $\alpha$ , yield predicted by the data of Ref. 9 is shown as open circles in (c). Peaks that could result from decays to  $^{20}\text{Ne}^{2+}$  (1.63 MeV) are labeled with a subscript 1. (The energy scale is appropriate to  $\alpha$ , decays.) The triangle points in (b) are the predictions of a H-F calculation for the decay of the GDR.

(over)

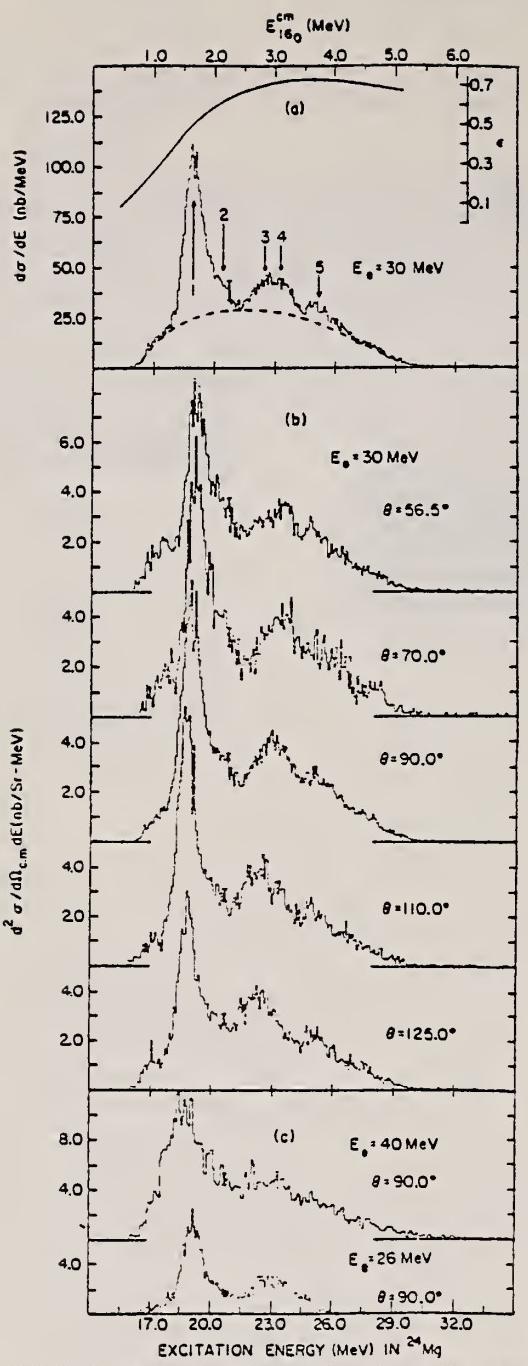


FIG. 2. Cross sections (in nanobarn/steradian per megaelectronvolt of excitation) for  $^{24}\text{Mg}(e, ^{16}\text{O} + \text{Be}e')$  are shown in (b) and (c). The angle-integrated spectrum, is shown in (a). The detection efficiency follows the solid curve in (a) with its scale on the right. A vertical bar on each spectrum at  $E_{ex} = 20.8 \text{ MeV}$  indicates the level of statistical uncertainty.

ELEM. SYM.	A	Z
Mg	24	12

## METHOD

REF. NO.

81 Ca 2

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	1 (1.368)	C	0 - 2	SCD-D		

**Abstract.** Lifetimes of 49 excited states below 1.65 MeV have been measured in  $^{24}\text{Mg}$ ,  $^{27}\text{Al}$ ,  $^{48}\text{Ti}$ ,  $^{58}\text{Ni}$ ,  $^{59}\text{Co}$ ,  $^{61,62}\text{Ni}$ ,  $^{63,65}\text{Cu}$ ,  $^{64,66,68}\text{Zn}$ ,  $^{75}\text{As}$ ,  $^{103}\text{Rh}$ ,  $^{113,115}\text{In}$ ,  $^{116,118,120}\text{Sn}$  and  $^{121,123}\text{Sb}$  by means of nuclear resonance fluorescence experiments. The levels are excited by bremsstrahlung x-ray photons. The self-absorption technique applied to suitable cases provides nuclear absorption cross sections, widths and lifetimes from which the x-ray spectral distributions are also obtained. Scattering experiments are performed for all other cases in order to obtain widths and lifetimes from these x-ray photon curves. The Compton effect in the sample is taken into account. Self-absorption provides  $g\Gamma_0$  from which  $\Gamma$  is deduced using adopted  $J^\pi$  and  $\Gamma_0/\Gamma$  values; scattering provides  $u=g(\Gamma_0^2/\Gamma)W(\theta)$  from which  $\Gamma$  is also deduced with  $J$ ,  $\Gamma_0/\Gamma$  and mixing ratios taken from the literature. Thanks to simultaneous determination of the x-ray spectra all the lifetimes as given by our programs with their statistical errors form an unusually coherent set of values.

1.358 MeV

NUCLEAR REACTIONS ( $\gamma, \gamma'$ ), bremsstrahlung excitation; natural isotopes;  $^{24}\text{Mg}$ ,  $^{27}\text{Al}$ ,  $^{48}\text{Ti}$ ,  $^{58}\text{Ni}$ ,  $^{59}\text{Co}$ ,  $^{61,62}\text{Ni}$ ,  $^{63,65}\text{Cu}$ ,  $^{64,66,68}\text{Zn}$ ,  $^{75}\text{As}$ ,  $^{103}\text{Rh}$ ,  $^{113,115}\text{In}$ ,  $^{116,118,120}\text{Sn}$  and  $^{121,123}\text{Sb}$ ;  $E \approx 0.5-1.65$  MeV; measured  $g\Gamma_0$  or  $g(\Gamma_0^2/\Gamma)W(\theta)$ ; deduced  $T_{1/2}$ .

(OVER)

Tableau 3. Résultats des mesures des niveaux étudiés par diffusion.

Table 3. Results obtained using the diffusion method.

Isotope	Energie (keV)	$J^*$	$J_0^*$	$\Gamma_0/\Gamma$	$\delta$	$u = g(\Gamma_0^2/\Gamma)W(\theta)$ (meV)	$\tau$ (ps) ce travail	$\tau_{ref}$ (ps)	Références†
<sup>24</sup> Mg	1368,59(4)	2 <sup>+</sup>	0 <sup>+</sup>	1	E2	1,08(13)	1,76(21)	1,98(4)	Endt et van der Leun (1978)
<sup>27</sup> Al	1014,45(3)	1 <sup>+</sup>	1 <sup>+</sup>	0,971	+ 0,351(12)	0,186(13)	2,20(16)	2,12(8)	Endt et van der Leun (1978)
<sup>48</sup> Ti	983,512(3)	2 <sup>+</sup>	0 <sup>+</sup>	1	E2	0,282(23)	6,74(55)	6,1(13)	Been (1978)
<sup>58</sup> Ni	1454,45(15)	2 <sup>+</sup>	0 <sup>+</sup>	1	E2	2,11(26)	0,90(11)	0,92(3)	Koehler et Auble (1976)
<sup>59</sup> Co	1099,224(25)	1 <sup>-</sup>	1 <sup>-</sup>	1	(E2)	0,069(8)	4,79(55)	3,17(58)	Kim (1976)
<sup>59</sup> Co	1458,8(3)	1 <sup>-</sup>	1 <sup>-</sup>	0,91	(E2)	0,68(8)	1,17(14)	1,52(16)	Kim (1976)
<sup>59</sup> Co	1480,9(3)	1 <sup>-</sup>	1 <sup>-</sup>	0,8	< 0,35 <sup>a</sup>	1,23(15)	0,254(31)	0,31(3)	Kim (1976)
<sup>61</sup> Ni	1185,7(6)	1 <sup>-</sup>	1 <sup>-</sup>	0,77(8) <sup>i</sup>	0,14	1,88(49)	0,21(5)	0,16(3)	Andreev et al (1974)
<sup>62</sup> Ni	1172,9(9)	2 <sup>+</sup>	0 <sup>+</sup>	1	E2	0,88(17)	2,15(42)	2,09(3)	Halbert (1979a)
<sup>63</sup> Cu	1327,00(7)	1 <sup>-</sup>	1 <sup>-</sup>	0,84	(E2)	1,04(14)	0,84(11)	0,88(4)	Auble (1979b)
<sup>63</sup> Cu	1412,05(4)	1 <sup>-</sup>	1 <sup>-</sup>	0,72	+ 0,61( <sup>b</sup> )	0,260(38)	1,90(28)	1,61(3)	Auble (1979b)
<sup>64</sup> Zn	991,54(7)	2 <sup>+</sup>	0 <sup>+</sup>	1	E2	0,640(54)	2,97(25)	2,60(13)	Halbert (1979b)
<sup>65</sup> Cu	1481,83(5)	1 <sup>-</sup>	1 <sup>-</sup>	0,85	(E2)	1,13(19)	0,79(13)	0,49(5)	Auble (1975a)
<sup>66</sup> Zn	1039,37(6)	2 <sup>+</sup>	0 <sup>+</sup>	1	E2	0,70(6)	2,71(23)	2,25(15)	Auble (1975b)
<sup>66</sup> Zn	1077,38(5)	2 <sup>+</sup>	0 <sup>+</sup>	1	E2	0,70(6)	2,71(23)	2,34(23)	Lewis (1975)
<sup>73</sup> As	572,5(10)	1 <sup>-</sup>	1 <sup>-</sup>	1 <sup>d</sup>	0,39 <sup>b</sup>	0,236(26)	4,14(46)	3,5(9)	Floren et Lewis (1975)
<sup>75</sup> As	823,0(10)	1 <sup>-</sup>	1 <sup>-</sup>	0,86 <sup>d</sup>	(E2)	0,214(22)	4,27(43)	3,5(3)	Robinson et al (1967)
<sup>75</sup> As	865,5(10)	1 <sup>-</sup>	1 <sup>-</sup>	0,83 <sup>d</sup>	— <sup>c</sup>	0,78(6)	0,863(68)	0,60(12)	Celliers et al (1977)
<sup>75</sup> As	1076,0(10)	1 <sup>-</sup>	1 <sup>-</sup>	0,94 <sup>d</sup>	0,38 <sup>d</sup>	1,97(13)	0,287(19)	0,32(7)	Celliers et al (1977)
<sup>75</sup> As	1128,5(10)	1 <sup>-</sup>	1 <sup>-</sup>	1	E1 <sup>d</sup>	0,224(24)	1,47(16)	—	
<sup>75</sup> As	1349,0(10)	1 <sup>-</sup>	1 <sup>-</sup>	0,67 <sup>d</sup>	0,20 <sup>d</sup>	1,61(29)	0,180(32)	0,12(3)	Wilson (1970)
<sup>75</sup> As	1370, <sup>e</sup> (10)	1 <sup>-</sup>	1 <sup>-</sup>	0,47 <sup>d</sup>	0,47 <sup>d</sup>	0,64(13)	0,218(44)	—	
<sup>103</sup> Rh	803,1(2)	1 <sup>-</sup>	1 <sup>-</sup>	0,70	M1	1,85(16)	0,174(15)	—	Harmatz (1979)
<sup>103</sup> Rh	1277,0(2)	1 <sup>-</sup>	1 <sup>-</sup>	0,75	- 0,62(30) <sup>e</sup>	0,81(9)	0,87(10)	1,3(9)	Harmatz (1979)
<sup>113</sup> In	1177(1)	1 <sup>-</sup>	1 <sup>-</sup>	1	+ 0,5(2)	9,1(8)	0,086(8)	0,10(6)	Tuttle et al (1976)
<sup>113</sup> In	1510(1)	1 <sup>-</sup>	1 <sup>-</sup>	0,935	- 0,5( <sup>b</sup> )	6,4(9)	0,071(10)	0,11( <sup>b</sup> )	Tuttle et al (1976)
<sup>115</sup> In	1077,7(10)	1 <sup>-</sup>	1 <sup>-</sup>	0,81 <sup>f</sup>	(E2)	0,159(24)	1,61(24)	1,23(7)	Tuttle et al (1976)
<sup>115</sup> In	1290,59(3)	1 <sup>-</sup>	1 <sup>-</sup>	0,98 <sup>f</sup>	(E2)	1,31(11)	0,66(6)	0,55(4)	Tuttle et al (1976)
<sup>115</sup> In	1448,78(3)	1 <sup>-</sup>	1 <sup>-</sup>	0,86	- 8 <sup>f</sup>	0,90(11)	0,50(6)	0,52(20)	Tuttle et al (1976)
<sup>115</sup> In	1486,1(11)	1 <sup>-</sup>	1 <sup>-</sup>	0,787	- 0,8 <sup>f</sup>	0,63(9)	0,63(9)	0,4(3)	Tuttle et al (1976)
<sup>115</sup> In	1497,2(4)	1 <sup>-</sup>	1 <sup>-</sup>	< 1	(E2)	1,33(16)	< 0,304 <sup>f</sup>	—	
<sup>115</sup> In	1607,8(15)	1 <sup>-</sup>	1 <sup>-</sup>	≤ 1	(E2)	1,54(24)	≤ 0,26(4)	—	
<sup>116</sup> Sn	1293,54(2)	2 <sup>+</sup>	0 <sup>+</sup>	1	E2	3,58(37)	0,53(6)	0,522(14)	Carlson et al (1975)
<sup>118</sup> Sn	1229,64(4)	2 <sup>+</sup>	0 <sup>+</sup>	1	E2	2,75(28)	0,69(7)	0,67(2)	Carlson et al (1976)
<sup>120</sup> Sn	1171,6(2)	2 <sup>+</sup>	0 <sup>+</sup>	1	E2	1,83(16)	1,04(9)	0,91(2)	Koehler (1976)
<sup>121</sup> Sb	1023,5(10)	2 <sup>+</sup>	1 <sup>-</sup>	1	0,57  <sup>b</sup>	3,69(34)	0,228(21)	0,20(7) <sup>h</sup>	Tanura et al (1979)
<sup>121</sup> Sb	1105,5(10)	2 <sup>+</sup>	1 <sup>-</sup>	0,4	—	0,47(4)	0,42(4)	—	
<sup>121</sup> Sb	1142,5(10)	2 <sup>+</sup>	1 <sup>-</sup>	0,6	(E2)	0,85(8)	0,449(40)	0,41(8) <sup>h</sup>	Booth et al (1973)
<sup>121</sup> Sb	1384,0(10)	2 <sup>+</sup>	1 <sup>-</sup>	0,45 <sup>b</sup>	0,45  <sup>b</sup>	4,7(5)	0,092(10)	0,088(14) <sup>h</sup>	Booth et al (1973)
<sup>123</sup> Sb	1029,5(10)	2 <sup>+</sup>	1 <sup>-</sup>	1	0,57  <sup>b</sup>	2,96(27)	0,272(25)	0,26(4) <sup>h</sup>	Booth et al (1973)
<sup>123</sup> Sb	1086,5(10)	2 <sup>+</sup>	1 <sup>-</sup>	1	δ  > 1,26 <sup>b</sup>	1,06(9)	0,67(6)	0,72(15) <sup>h</sup>	Booth et al (1973)

† Références pour les colonnes 3, 4, 5, 6 et 9 de chaque ligne, sauf indication appelée au bas de ce tableau. Pour les autres données se reporter au texte.

Remarque. Pour calculer  $\delta^2$  quand nous ne disposons que de  $B(E2)$ , pour un mélange (E2) + (M1), nous déduisons  $g\Gamma_0(E2) \propto B(E2)\Gamma^3$ , en admettant  $W(\theta) = 1$  et connaissant  $\Gamma_0/\Gamma$ , notre détermination de  $u$  donne une première approximation de  $g\Gamma_0$  d'où une valeur de  $\delta^2 = (g\Gamma_0(E2))/(g\Gamma_0 - g\Gamma_0(E2))$  qui permet d'améliorer  $W(\theta)$  et  $g\Gamma_0$  de proche en proche.

<sup>a</sup> Swann (1971); <sup>b</sup> Robinson et al (1967); <sup>c</sup>  $W(\theta) = 0,99$  calculé d'après la formule de Celliers et al (1977); <sup>d</sup> Abbondanno et al (1978); <sup>e</sup> Sayer et al (1972); <sup>f</sup> Tuttle et al (1976); <sup>g</sup> d'après  $B(E2)$  de Barnes et al (1966); <sup>h</sup> calculé d'après Booth et al (1973); <sup>i</sup> Williams et al (1975); <sup>j</sup> Dietrich et al (1970).

ELEM. SYM.	A	Z
Mg	24	12
REF. NO.	81 It 1	hg

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE	RANGE	
E, E/	ABX	9-34	D	102-200	MAG-D

Highly excited multipole resonances of  $^{24}\text{Mg}$  between 9 and 34 MeV excitation energy have been investigated by inelastic electron scattering for incident energies in the 102 and 200 MeV range. Prominent giant dipole resonances were observed at 18.9 and 20 MeV excitation energy, with a shape which is very similar to the shape of the photoneutron cross section. Over twenty-five quadrupole and twenty octupole resonances were identified and separated by means of the multipole expansion method. The giant dipole strength exhausts  $(85 \pm 17)\%$  of the isovector dipole energy-weighted sum rule. The quadrupole and the octupole strength exhaust  $(117 \pm 23)\%$  and  $(115 \pm 23)\%$  of the corresponding isoscalar energy-weighted sum rule, respectively. Evidence for the excitation of higher multipole states such as hexadecapole transitions was also found in the excitation energy region studied.

[NUCLEAR REACTIONS  $^{24}\text{Mg}(e, e')$ ,  $E = 102, 125, 150, 200$  MeV,  $q = 0.37-1.3$  fm $^{-1}$ , measured  $\sigma(E', \theta)$  up to 34 MeV in excitation energy; deduced dipole, quadrupole, and octupole strengths in giant resonance region. Enriched targets.]

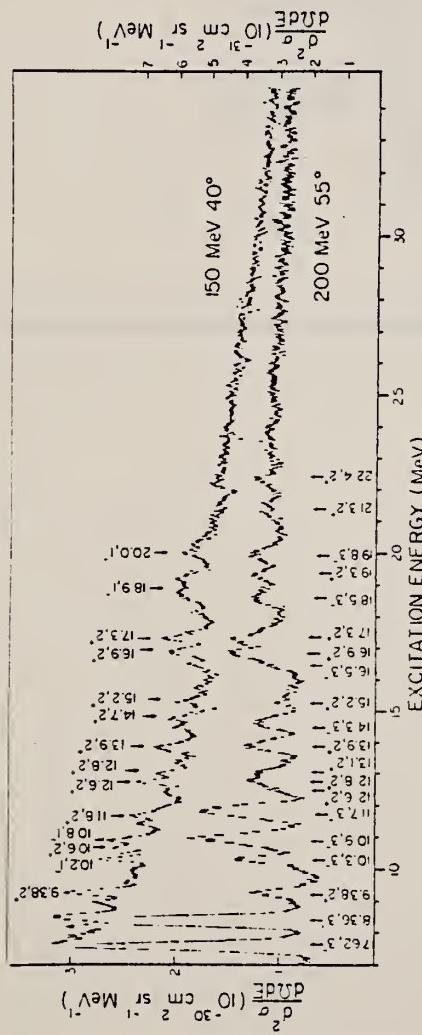
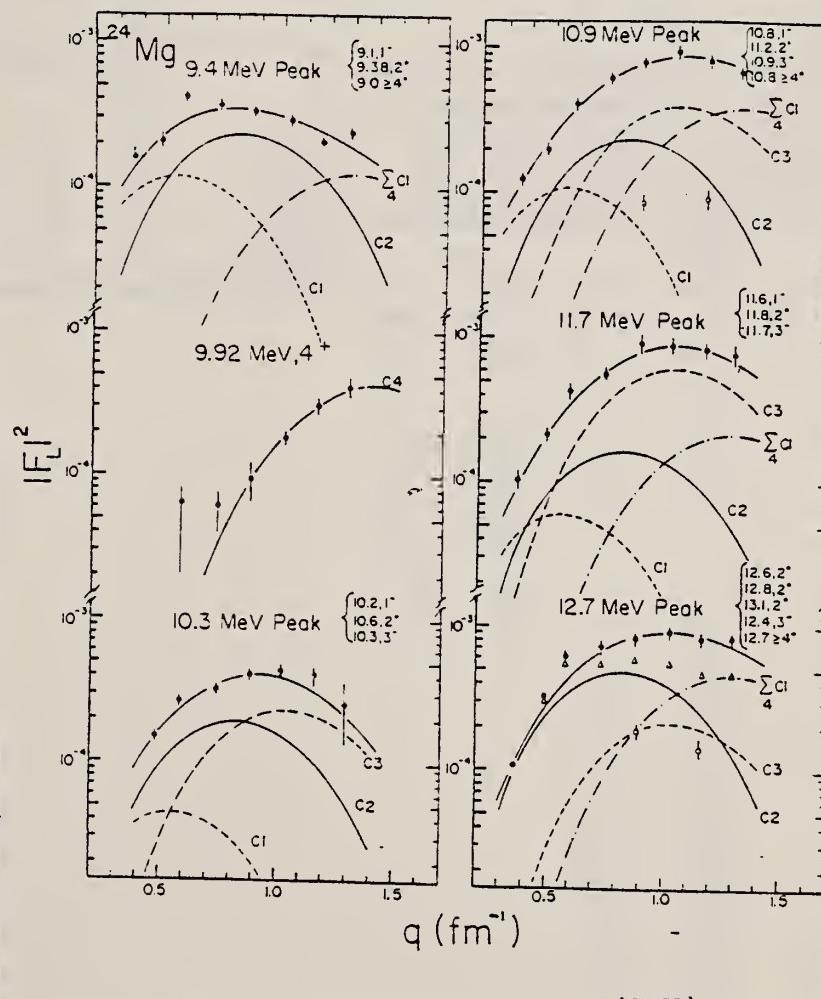


FIG. 1. Typical scattered electron spectra from  $^{24}\text{Mg}$  obtained at 150 and 200 MeV incident electron energy and scattering angles of 40° and 55°, respectively. The right-hand scale is for the 200 MeV spectrum, and the left-hand scale for the 150 MeV spectrum.



(OVER)

FIG. 2. Longitudinal form factors as decomposed according to the multipole expansion. Open circles indicate the contributions of the transverse excitations. The triangles are the form factors obtained by subtracting the phenomenological shape for the underlying continuum, as described in the text.

TABLE I. Reduced transition probabilities  $B(C1, t)$  and percentage of the isovector energy-weighted sum rule  $S_1$ . The errors are  $\pm 10\%$ ,  $\pm 20\%$ . The  $(\gamma, n)$  data were taken from Ref. 14.

$E_x$ (MeV)	Present		$(\gamma, n)$	
	$B(C1, t)$ ( $e^2 \text{fm}^2$ )	$S_1$ (%)	$E_x$ (MeV)	$S_1$ (%)
9.1	0.11	1.1		
10.2	0.039	0.44		
10.8	0.10	1.2		
11.6	0.054	0.71		
13.7	0.043	0.67		
14.4	0.077	1.2		
15.0	0.026	0.45		
16.7	0.22	4.2	16.9	0.16
17.1	0.12	2.3	17.3	0.29
			17.6	0.015
			18.3	0.84
18.9(17.7-19.5)	0.75	15.9	18.8	1.1
			19.2	0.79
20.0(19.5-20.3)	0.33	7.5	20.1	2.0
			20.4	0.29
20.3-21.4	0.28	6.5	20.9	1.2
21.4-25.0	0.77	20.0	21.5	0.41
			22.4	0.27
			23.1	2.0
25.0-28.0	0.39	10.5	25.0	4.2
			27.5	3.2
			16.5-	16.7
			28.0	
28.0-31.0	0.22	6.5		
31.0-34.0	0.16	5.8		
9.0-34.0	3.69	84.9		

TABLE III.  $B(C3, t)$  and percentage of the isoscalar octupole EWSR  $S_3$ . The errors are  $\pm 10\%$  up to 16.5 MeV,  $\pm 25\%$  above 17 MeV.  $B(C3)$  for the lowest two states were taken from previous  $(e, e')$  work of Ref. 12. The result of the  $(p, p')$  was taken from Ref. 9.

$E_x$ (MeV)	Present		$(p, p')$	
	$B(C3, t)$ $10^3 e^2 \text{fm}^3$	$S_3$ (%)	$E_x$ (MeV)	$S_3$ (%)
7.62	1.33	5.3	7.616	4.99
8.36	1.90	8.2	8.356	4.26
9.1	0.04	0.2		
10.3	0.26	1.4		
10.9	0.47	2.7	11.157	1.24
			11.318	0.31
11.7	0.71	4.3	12.016	0.58
12.4	0.24	1.5	12.261	0.39
			12.663	0.39
			12.850	0.30
				0.77
			13.344	0.33
			13.440	0.60
13.7	0.21	1.5		
14.3	0.31	2.3		
16.5	0.78	6.6		
17.1	0.18	1.6		
17.9	0.18	1.7		
18.5	0.36	3.5		
19.1	0.13	1.3		
19.8	0.34	3.5		
20.7	0.12	1.3		
21.1	0.23	2.5		
21.6	0.20	2.2		
22.0	0.42	4.8		
22.8	0.18	2.1		
23.4	0.41	4.9		
23.9-25.0	0.26	3.3		
25.0-28.0	1.04	9.3		
28.0-31.0	0.92	14.1		
31.0-34.0	1.51	25.5		
0-34.0	12.7	115		

TABLE II.  $B(C2, t)$  and percentage of the isoscalar quadrupole EWSR  $S_2$ . The errors are  $\pm 10\%$  up to 15.7 MeV,  $\pm 20\%$  above 16 MeV in excitation energy.  $B(C2, t)$  for the two lowest states were taken from the  $(e, e')$  work of Ref. 22. The  $\alpha$ -particle scattering data were taken from Ref. 7.  $S_2$  for the  $\alpha$ -capture reaction were calculated by Bertrand *et al.* (Ref. 7) using the data of Ref. 3. The previous  $(e, e')$  data were taken from Ref. 12.

$E_x$ (MeV)	Present		$(\alpha, \alpha')$		$(\alpha, \gamma_0)$		$(e, e')$	
	$B(C2, t)$ ( $e^2 \text{fm}^4$ )	$S_2$ (%)	$E_x$ (MeV)	$S_2$ (%)	$E_x$ (MeV)	$S_2$ (%)	$E_x$ (MeV)	$S_2$ (%)
1.37	446	13.3					1.37	12.4
4.23	22.8	2.1					4.23	2.4
7.34	0.9	0.2						
9.38	9.4	1.9					9.30	2.4
10.6	7.6	1.7						
11.2	9.7	2.4					11.38	0.6
11.8	6.8	1.8						
12.6							12.52	0.6
12.8	20.0	5.6	12.8	3.5	12.8	4.0	12.99	0.6
13.1			13.1	3.6	13.1	2.8		
13.9	11.3	3.4	13.9	3.0	13.9	0.4		
14.7	10.7	3.4	14.5	3.3				
			14.9	2.5				
15.2							15.8	0.6
15.7			11.0	3.7				
							16.6	2.3
			7.5	2.7	17.0	5.3	16.5	1.1
					17.8	3.1		
					18.2	2.5	18.2	0.5
			6.3	2.6	18.8	4.8		
					19.1	2.0		
					19.6	5.2		
			20.1		20.0	2.3	20.0	1.0
					20.4	6.8		
			20.8	2.1	21.1	(2.7)		
			21.3	7.8	21.4	(2.8)		
			22.4	8.4	21.7	5.4		
			22.7-25.0	20.6	10.1	24.0	7.9	
			25.0-28.0	29.4	17.0			
			28.0-31.0	28.5	18.3			
			31.0-34.0	10.0	7.0			
			0-34.0	705	117			

REF. H. Zarek, S. Yen, B.O. Pich, T.E. Drake, C.F. Williamson, S. Kowalski, C.P. Sargent, W. Chung, B.H. Wildenthal, M. Harvey, H.C. Lee Phys. Lett. <u>104B</u> , 499 (1981)	ELEM. SYM.	A	Z
	Mg	24	12

METHOD			REF. NO.	.		
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE	RANGE		
E,E/	FMF	4	D	1*2	MAG-D	DST

ERRATA FOR 78ZA2

ERRATA

H. Zarek et al., Electroexcitation and the determination of the  $K$ -band structure in  $^{24}\text{Mg}$ , Phys. Lett. 80B (1978) 26.

On page 27 in table 1,  $B(E4\uparrow)$  to the  $4_1^+$  state is  $(3.8 \pm 0.3) \times 10^3 \text{ e}^2\text{fm}^8$  and *not*  $(2.0 \pm 0.3) \times 10^3 \text{ e}^2\text{fm}^8$ .

\* \* \*



MG  
A=25

MG  
A=25

MG  
A=25



Elem. Sym.	A	Z
Mg	25	12

Method  $\text{BF}_3$  counters; 24 MeV Bremss Betatron.

Ref. No.  
55 Na 1  
EGF

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes	320
$(\gamma, xn)$	9.3-24	20.3	5	0.096 MeV-mb		<p><math>E_{th} = 7.3</math> MeV; <math>\sigma_{max} = 16.5</math> mb.</p> <p>No corrections.</p> <p>[NOTE: Figure 2:            Ref 8: Katz, Baker, Montalbetti,            Can. J. Phys. 31, 250 (1953).            Ref 5: Katz, Haslam, Goldemberg,            Taylor, Can. J. Phys. 32,            580 (1954).            Ref 9: Katz and Cameron, Phys. Rev.            84, 1115 (1951).            Ref 10: Toms, Stephens, Phys. Rev.            82, 709 (1951).]</p>	

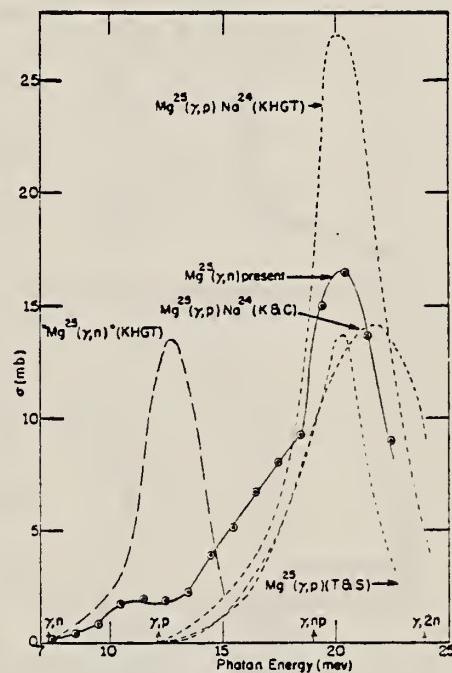


FIG. 2.  $(\gamma, n)$  cross section for  $\text{Mg}^{25}$ . The ordinate scale is in millibarns ( $10^{-27} \text{ cm}^2$ ). The locations of the thresholds for various reactions are indicated by arrows. The circles are the points calculated from the yield data. The solid curve is drawn to fit the points. The three dotted curves are the previously reported  $\text{Mg}^{25}(\gamma, p)\text{Na}^{24}$  cross sections (see references 5, 9, and 10). The dashed curve is the estimate of the  $\text{Mg}^{25}(\gamma, n)$  cross section made previously by subtracting the  $\text{Mg}^{24}(\gamma, n)$  of reference 8 from the measured cross section for natural Mg (see reference 5).

Method Protons from Bartol-ONR generator; ( $p, p'\gamma$ ), etc. reactions for $\gamma$ source; ring scatterer; NaI.		Ref. No. 60 Me 1	JHH
-----------------------------------------------------------------------------------------------------------------------------	--	---------------------	-----

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$(\gamma, \gamma)$	1.61		$3.0 \pm 1.5 \times 10^{-2}$ ev		$3/2^+$	

Elem. Sym.	A	Z
Mg	25	12

Method Van de Graaff; 1.61 MeV  $\gamma$  source by  $Mg^{25}(p, p'\gamma)$  with 4.0 MeV protons; ring scatterer; NaI.

Ref. No.	
61 Ra 1	JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$(\gamma, \gamma)$	1.61	1.61			(7/2+)	Assuming level to be 7/2+, mean life is $(2.5^{+0.6}_{-0.4}) \times 10^{-14}$ sec. Angular distribution fitted to $1 + (0.42 \pm 0.03)P_2 \cos\theta + (0.03 \pm 0.003)P_4 \cos^2\theta$ but $P_4$ term probably about zero.

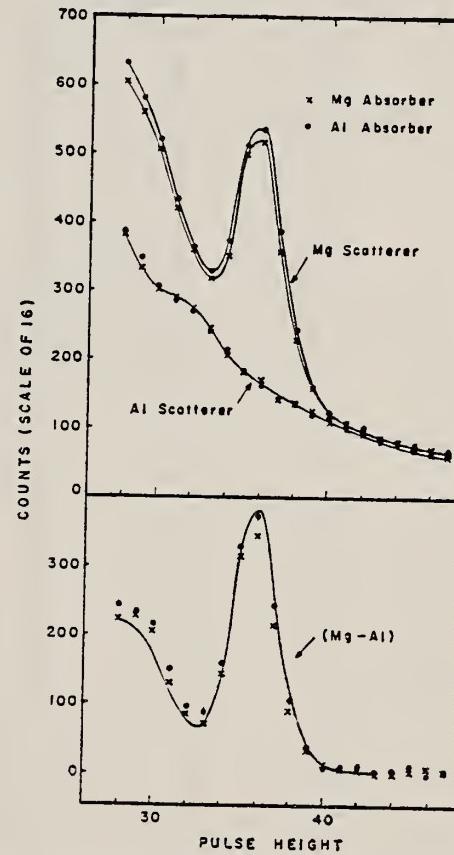


FIG. 3. Resonant scattering of the 1.61-Mev  $\gamma$  ray from  $Mg^{25}$ . The upper curves give the original data for the scatterer-absorber combinations noted. Statistical errors can be estimated from the left-hand scale which gives the total number of counts for each point. Magnesium scatterer-aluminum scatterer differences are shown in the lower plot, where the solid curve drawn is the shape found for an isolated 1.61-Mev  $\gamma$  ray from a radioactive source and is normalized to the aluminum absorber data. The sum of the counts for pulse heights 34 to 37 was taken to represent the resonance effect.

	Elem. Sym.	A	Z
	Mg	25	12

Method 4 MeV electron Van de Graaff; bremss.; nuclear resonance scattering, ring scatterer; NaI

Ref. No.	
62 Bo-6	JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes		
Mg <sup>25</sup> ( $\gamma, \gamma$ )	Bremss. 0 - 4							

TABLE 2  
Comparison of mean lifetime measurements

Nucleus	Energy	$\%$	Spins	$\epsilon$	$\Gamma_0/\Gamma$	$W(\theta)$	$\tau \times 10^{14} \text{ sec}$	
							This work	Other
Li <sup>6</sup>	3.56	7	$1^+ - 0^-$	$\frac{1}{2}$	(1)	1	0.012	$0.0072 \pm 0.0013$
								$0.0105 \pm 0.001$ (1)
Be <sup>9</sup>	2.14	81	$\frac{1}{2}^+ - \frac{1}{2}^+$	$\frac{1}{2}$	1	1	0.53	$0.47 \pm 0.06$ (1)
Al <sup>27</sup>	2.21	100	$\frac{1}{2}^+ - \frac{3}{2}^+$	$\frac{1}{2}$	(1)	1	3.2	$2.7 \pm 0.3$ (1)
Al <sup>27</sup>	1.01	100	$\frac{1}{2}^+ - \frac{3}{2}^+$	$\frac{1}{2}$	0.98	1	520	$\leq 50$ (1)
Si <sup>28</sup>	1.78	92	$0^+ - 2^+$	5	1	0.63	88	$73 \pm 22$ (1)
Si <sup>28</sup>	2.24	98	$0^+ - 2^+$	5	1	0.63	28	$\approx 18$ (1)
Mg <sup>24</sup>	1.37	78.6	$0^+ - 2^+$	5	1	0.63	220	$155 \pm 40$ (1)
Mg <sup>24</sup>	1.81	25	$\frac{1}{2}^+ - \frac{3}{2}^+$	$\frac{1}{2}$	(1)	1	3.6	$2.5 \pm 0.6$ (1)
Cu <sup>65</sup>	0.943	69	$\frac{1}{2}^- - \frac{1}{2}^+$	$\frac{1}{2}$	1	0.92	230	$72 \pm 18$ (1)
Cu <sup>65</sup>	0.67	69	$\frac{3}{2}^- - \frac{1}{2}^+$	$\frac{1}{2}$	1	1	100	$31 \pm 3$ (1)

The factor  $\epsilon$  equals  $(2I + 1)(M_J + 1)^{-1}$ .

- 10) R. C. Hansen, Phys. Rev. 146 (1966) 1466
- 11) S. Vopson, L. Maradudin and R. Heath, IDO-10870
- 12) Leslie Cohen and Ralph Tolman, Nuclear Physics 16 (1959) 243
- 13) W. C. Barber, F. Berthold, G. Fricks and F. E. Gudden, Phys. Rev. 130 (1960) 2128
- 14) F. R. Metzger, C. P. Swann and V. K. Raamussen, Phys. Rev. 110 (1958) 906
- 15) F. R. Metzger, C. P. Swann and V. K. Raamussen, Nuclear Physics 16 (1960) 568
- 16) S. Ofer and A. Schwarzschild, Phys. Rev. Lett. 3 (1959) 354
- 17) V. K. Raamussen, F. R. Metzger and C. P. Swann, Phys. Rev. 123 (1961) 1386
- 18) J. B. Cummings, A. Schwarzschild, A. W. Sunyar and N. T. Porte, Phys. Rev. 120 (1960) 2128
- 19) T. Rothen, F. R. Metzger and C. P. Swann, Nuclear Physics 22 (1961) 508

ELEM. SYM.	A	Z
Mg	25	12

METHOD

Van de Graaff; resonance fluorescence

REF. NO.

64 Bo 1

NVB

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	1-3 (0.5 - 3.0)	C	1 - 3 (0.5 - 3.0)	NAI-D		100

ABI

TABLE I  
 Cases of observed resonance fluorescence

Nucleus multipol.	State (MeV)	Spin	$\Gamma_0/\Gamma$	$T(gw\Gamma_0^2/\Gamma^2)^{-1}$ (sec.)	Mean lifetime $T$ BCW (sec)	Mean lifetime $T$ other (sec)	Ref.	$\Gamma_0/\Gamma_W$ BCW
Mg <sup>25</sup>	0.00	$\frac{1}{2}^-$						
M1	1.61	$\frac{1}{2}^+$	1	$21 \pm 5 \times 10^{-15}$	$28 \pm 7 \times 10^{-15}$	$25 \pm 4 \times 10^{-15}$	II)	0.085

REF.

I. Bergqvist, J. A. Biggerstaff, J. H. Gibbons, W. M. Good  
 Phys. Rev. 158, 1049 (1967)

ELEM. SYM.	A	Z
Mg	25	12

## METHOD

REF. NO.

67 Be 7

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
N, G	LFT	7	D	1	NaI-D	0-7	90

SOURCE 84 KEV

TABLE IV. Gamma rays from  $^{24}\text{Mg}(\text{n},\gamma)^{25}\text{Mg}$ ;  $E_{\text{n}} = 84 \text{ keV}$ ,  $J^{\pi} = \frac{1}{2}^-$ .

$E_{\gamma}$ (MeV)	$I_{\gamma}$ (per 100 captures)	Assignment	$J_i^{\pi} \rightarrow J_f^{\pi}$	$\Gamma_{\gamma_i}$ (meV)	$1000 M $
7.41	18±1	$C \rightarrow 0$	$\frac{1}{2}^- \rightarrow \frac{1}{2}^+$	630	2.7
6.83	67±2	$C \rightarrow 0.58$	$\frac{1}{2}^- \rightarrow \frac{1}{2}^+$	2350	13.
5.45	2.5±1.0	$C \rightarrow 1.96$	$\frac{1}{2}^- \rightarrow \frac{1}{2}^+$	85	0.9
4.84	12.5±1.5	$C \rightarrow 2.57$	$\frac{1}{2}^- \rightarrow \frac{1}{2}^+$	440	6.7
(3.9)*	(1.4)				
(3.25)	(1.2)				
(2.8)	(2)				
(2.5)	(2.4)				
1.98	11.1±0.9	{ 2.57 → 0.58 1.96 → 0 2.57 → 0.98 (1.61 → 0)}	{ $\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$ $\frac{1}{2}^+ \rightarrow \frac{1}{2}^-$ $\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$ $((\frac{1}{2}^+) \rightarrow (\frac{1}{2}^+))$		
1.58	3.3±0.4	1.96 → 0.58			
1.38	2.4±0.4	1.96 → 0.98			
0.98	5.7±0.8	{ 1.96 → 0.98 0.98 → 0 }	{ $\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$ $\frac{1}{2}^+ \rightarrow \frac{1}{2}^+$		

\* Parentheses imply marginal credibility.

METHOD

REF. NO.

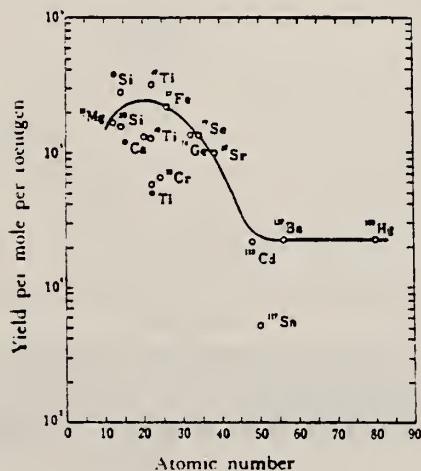
68 Ok 3

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, P	ABY	THR-20	C	20	ACT-I		4PI

TABLE I. SUMMARY OF DATA ON ( $\gamma$ , p) REACTIONS WITH 20 MeV BREMSSTRAHLUNG

Nuclide	Parent (Natural abundance, %)	Residual (Half-life)	$S_p$ (MeV)	Observed $\gamma$ -ray			Yield determined	
				Energy (MeV)	Branching ratio (%)	Type of multipole transition	$\mu\text{Ci}/\text{mg}^{20}$	Yield/mol·R
$^{23}\text{Mg}$	(10.11)	$^{24}\text{Na}$ (15 hr)	12.06	1.37	100	E2	$1.48 \times 10^{-1}$	$1.7 \times 10^3$
$^{29}\text{Si}$	(4.71)	$^{28}\text{Al}$ (2.27 min)	12.33	1.78	100	E2	1.91	$2.8 \times 10^4$
$^{20}\text{Si}$	(3.12)	$^{20}\text{Al}$ (6.56 min)	13.59	1.28	93.8	E2+M1	$6.51 \times 10^{-1}$	$1.5 \times 10^3$
$^{44}\text{Ca}$	(2.06)	$^{42}\text{K}$ (22.4 hr)	12.17	0.374	85	E2+M1	$7.86 \times 10^{-2}$	$1.3 \times 10^3$
$^{44}\text{Ti}$	(7.32)	$^{46}\text{Sc}$ (84.1 d)	10.47	0.887	100	E2	$7.11 \times 10^{-4}$	$3.1 \times 10^3$
$^{48}\text{Ti}$	(73.99)	$^{47}\text{Sc}$ (3.4 d)	11.44	0.160	100	E2+M1	$6.83 \times 10^{-3}$	$1.2 \times 10^4$
$^{48}\text{Ti}$	(5.46)	$^{48}\text{Sc}$ (1.8 d)	11.35	1.31	100	E2	$4.40 \times 10^{-3}$	$5.8 \times 10^4$
$^{52}\text{Cr}$	(9.55)	$^{53}\text{V}$ (3.8 min)	11.15	1.43	100	E2	$5.01 \times 10^{-1}$	$6.6 \times 10^4$
$^{57}\text{Fe}$	(2.17)	$^{56}\text{Mn}$ (2.58 hr)	10.57	1.81	23.5	E2+M1	$8.10 \times 10^{-2}$	$2.1 \times 10^3$
$^{74}\text{Ge}$	(36.74)	$^{73}\text{Ga}$ (4.8 hr)	10.92	0.295	97	(E2)	$3.70 \times 10^{-1}$	$1.3 \times 10^3$
$^{77}\text{Se}$	(7.58)	$^{76}\text{As}$ (26.5 hr)	9.61	0.559	41	E2	$1.48 \times 10^{-3}$	$1.3 \times 10^3$
$^{87}\text{Sr}$	(7.02)	$^{86}\text{Rb}$ (19 d)	9.41	1.08	9	E2	$5.15 \times 10^{-4}$	$9.9 \times 10^4$
$^{113}\text{Cd}$	(12.26)	$^{112}\text{Ag}$ (3.2 hr)	9.74	1.39	35	E2	$1.91 \times 10^{-2}$	$2.1 \times 10^4$
$^{117}\text{Sn}$	(7.57)	$^{116m}\text{In}$ (54 min)	9.58	1.27	84	E2	$9.80 \times 10^{-1}$	$6.9 \times 10^3$
$^{127}\text{Ba}$	(11.32)	$^{136}\text{Cs}$ (13 d)	8.67	0.830	100	E2	$1.68 \times 10^{-4}$	$2.2 \times 10^4$
$^{199}\text{Hg}$	(16.84)	$^{198}\text{Au}$ (2.7 d)	7.27	0.412	100	E2	$8.43 \times 10^{-4}$	$2.2 \times 10^4$

a) The value corrected at the end of 1 hr irradiation ( $9.4 \times 10^6$  R/min).Fig. 2. The yield curve for the ( $\gamma$ , p) reaction with 20 MeV bremsstrahlung.



## METHOD

REF. NO.

25

12

REF. NO.

69 Fa 2

home

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,E/	ABX	0-27	D	39,56	MAG-D	30-56	180
				(38.9,55.9)			

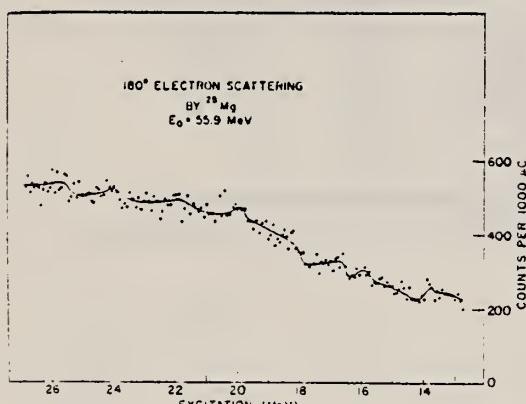


FIG. 1. Spectrum obtained from  $180^\circ$  electron scattering by  $^{24}\text{Mg}$  with  $E_0 = 55.9$  MeV, covering the excitation energy range 12-27 MeV.

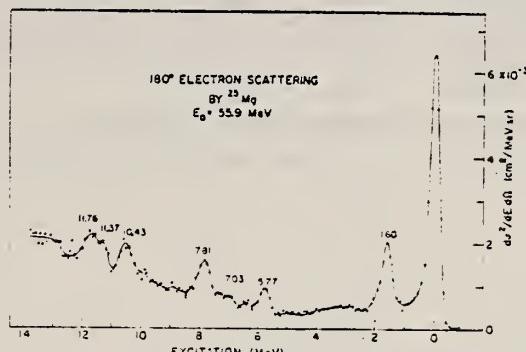


FIG. 2. Differential cross section for  $180^\circ$  electron scattering from  $^{24}\text{Mg}$  with  $E_0 = 55.9$  MeV, covering the excitation energy range 0-12 MeV.

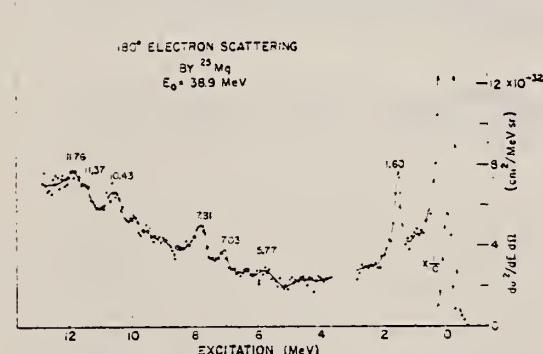


Fig. 3. Differential cross section for  $180^\circ$  electron scattering from  $^{25}\text{Mg}$  with  $E_0 = 38.9$  MeV, covering the excitation energy range 0–12 MeV. The gap in the spectrum arises from the fact that a preliminary survey, as well as the 56-MeV data, showed no structure of interest in this region; thus presentable data were not accumulated here.

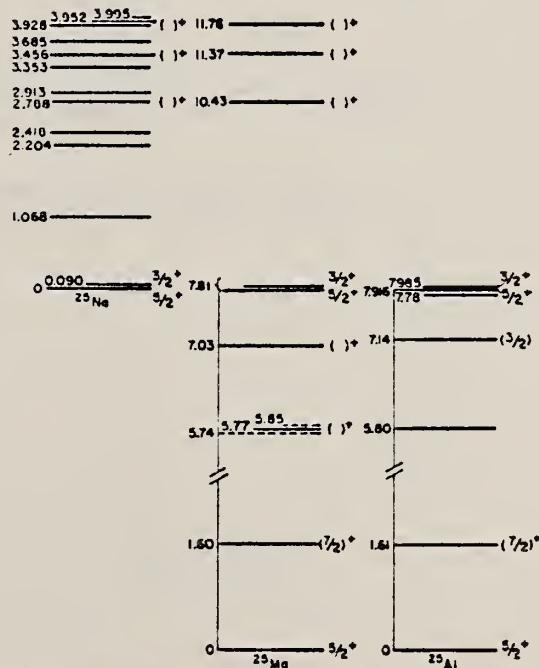


FIG. 4. Energy-level diagram adjusted for the Coulomb displacement showing  $^{24}\text{Na}$ ,  $^{24}\text{Mg}$ , and  $^{24}\text{Al}$  analog states. In the  $^{24}\text{Mg}$  scheme only states excited and analyzed in this work are shown with solid lines. Some corresponding  $^{24}\text{Al}$  states are shown. Energy values given in the  $^{24}\text{Na}$  and  $^{24}\text{Al}$  level schemes are those quoted from Ref. 18 except for the 7.916- and 7.983-MeV levels quoted from Ref. 5.

<sup>5</sup>G.C. Morrison, D.H. Youngblood, R.C. Bearse, R.E. Segel, Phys. Rev. 174, 1366 ('68).  
<sup>18</sup>P.M. Endt, C. Van der Leun, Nucl. Phys. A105, 1 (1967). 372

TABLE I. Values of differential cross section, isospin, spin and parity, spin projection on the nuclear axis, transition radius, and radiation width for energy levels excited in  $^{24}\text{Mg}$ .

Level energy (MeV)	Plane-wave Born approximation						DWBA corrections		
	$(d\sigma/d\Omega)_{10}$ ( $10^{-24} \text{ cm}^2/\text{sr}$ )	$T$	$J^\pi$	$K^\pi$	$R_M$ (fm)	$\frac{2J+1}{2J_0+1} \Gamma_0$	$R_M$ (fm)	$\frac{2J+1}{2J_0+1} \Gamma_0$	
						(eV)		(eV)	
1.60 $\pm$ 0.02	91 $\pm$ 7	158 $\pm$ 15	$\frac{1}{2}$	$\frac{1}{2}^+$	2.7	0.078	$2.4_{-0.4}^{+0.2}$	$0.055_{-0.012}^{+0.014}$	
5.77 $\pm$ 0.04	27 $\pm$ 3	38 $\pm$ 8	$\frac{1}{2}$	$(\frac{3}{2}^+)$	( $\frac{3}{2}^+$ )	2.4	0.83	$2.0_{-1.5}^{+0.4}$	
7.03 $\pm$ 0.05	13 $\pm$ 4	42 $\pm$ 8	$\frac{1}{2}$	$(\frac{1}{2}^+)$	( $\frac{1}{2}^+$ )	3.8	2.9	$3.7 \pm 0.5$	
7.81 $\pm$ 0.03	59 $\pm$ 4	100 $\pm$ 10	$\frac{1}{2}$	$\frac{3}{2}^+, \frac{1}{2}^+$	$\frac{3}{2}^+$	2.9	6.5	$2.6_{-0.4}^{+0.2}$	
10.43 $\pm$ 0.05	39 $\pm$ 6	104 $\pm$ 15	( $\frac{3}{2}^-$ )	( $\frac{1}{2}^-$ ) <sup>a</sup>	( $\frac{1}{2}^-$ ) <sup>a</sup>	3.7	22	$3.5 \pm 0.3$	
11.37 $\pm$ 0.07	34 $\pm$ 8	68 $\pm$ 15	( $\frac{3}{2}^-$ )	( $\frac{1}{2}^-$ ) <sup>a</sup>	( $\frac{1}{2}^-$ ) <sup>a</sup>	3.3	16	$3.0_{-0.8}^{+0.6}$	
11.76 $\pm$ 0.06	41 $\pm$ 8	87 $\pm$ 16	( $\frac{3}{2}^-$ )	( $\frac{1}{2}^-$ ) <sup>a</sup>	( $\frac{1}{2}^-$ ) <sup>a</sup>	3.4	24	$3.2_{-0.6}^{+0.4}$	
								$18_{-4}^{+7}$	

<sup>a</sup>  $\frac{1}{2}^-, \frac{3}{2}^+$ , or  $\frac{5}{2}^+$ .

METHOD

REF. NO.

70 Be 5

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N	ABX	7-10	C	11	TOF-D		135
							947+

The photoneutron cross section for  $Mg^{25}$  has been measured from 30 to 2000 keV above threshold. The locations of the isobaric analogs of the ground and first excited states of  $Na^{25}$  have been assigned and lower limits for their neutron-decay widths have been determined.

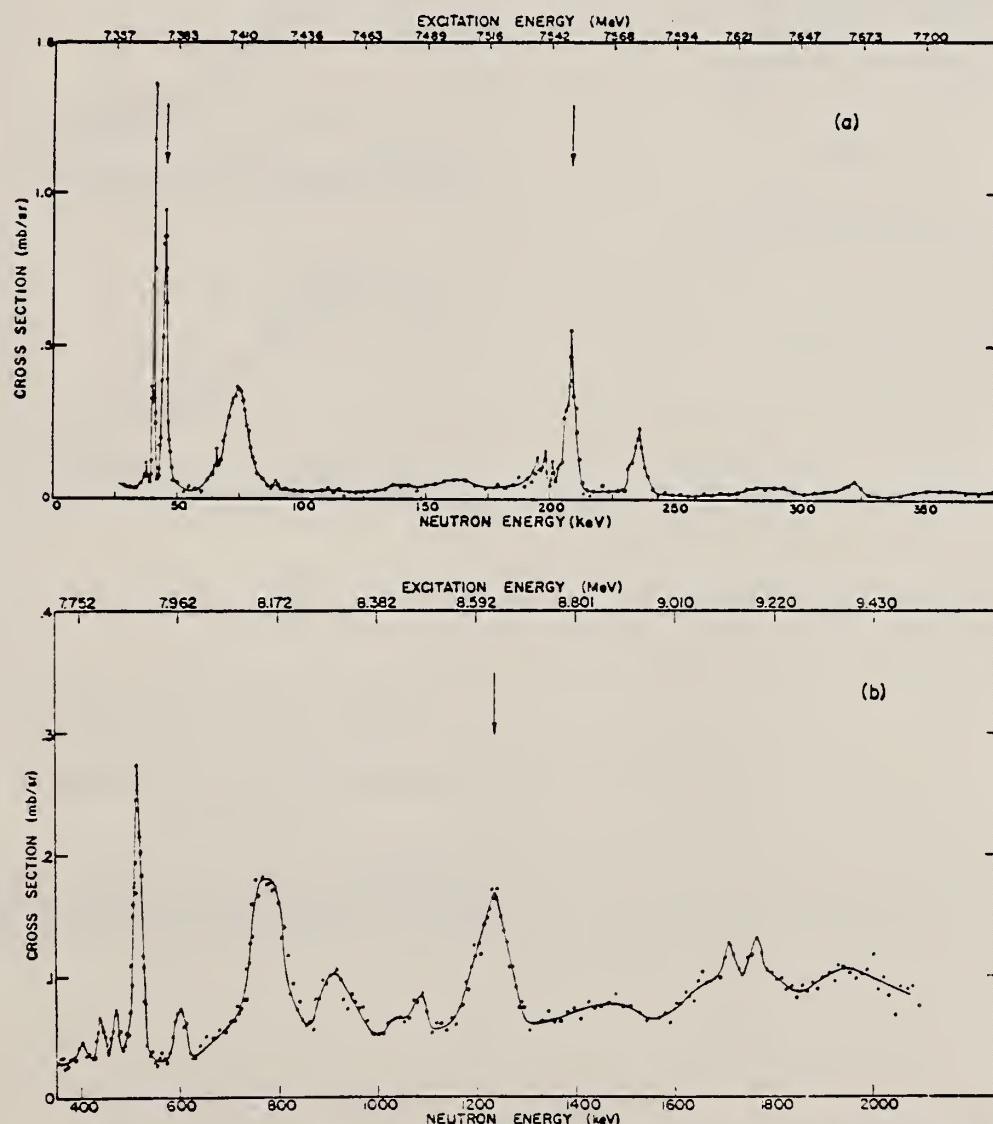
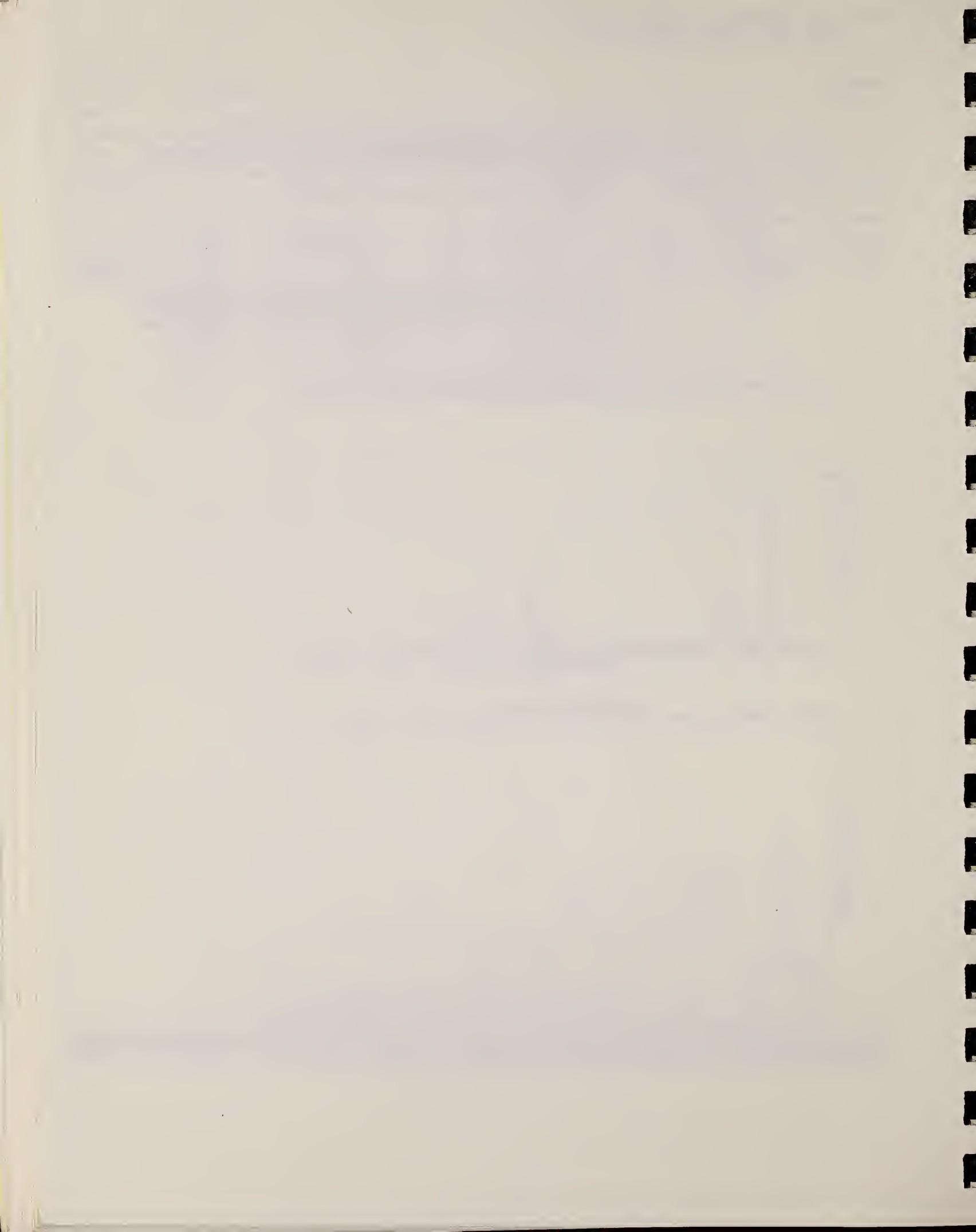


FIG. 1. Differential photoneutron cross section for  $Mg^{25}$  at  $135^\circ$  as a function of laboratory neutron energy (lower scale) and of excitation energy (upper scale). The arrows refer to peaks resulting from transitions to the first excited state of  $Mg^{24}$ . (a) Low-energy cross section; (b) high-energy cross section.



REF.

R. A. Alvarez, B. L. Berman, D. R. Lasher, T. W. Phillips, and  
 S. C. Fultz  
 Phys. Rev. C4, 1673 (1971)

ELEM. SYM.

Mg

25

12

Z

METHOD

REF. NO.

71 Al 1

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N 352	ABX	7-29	D	7-29	BF3-I		4PI *
G, 2N 353†	ABX	23-29	D	23-29	BF3-I		4PI

\* INCLUDES G, NP 352†

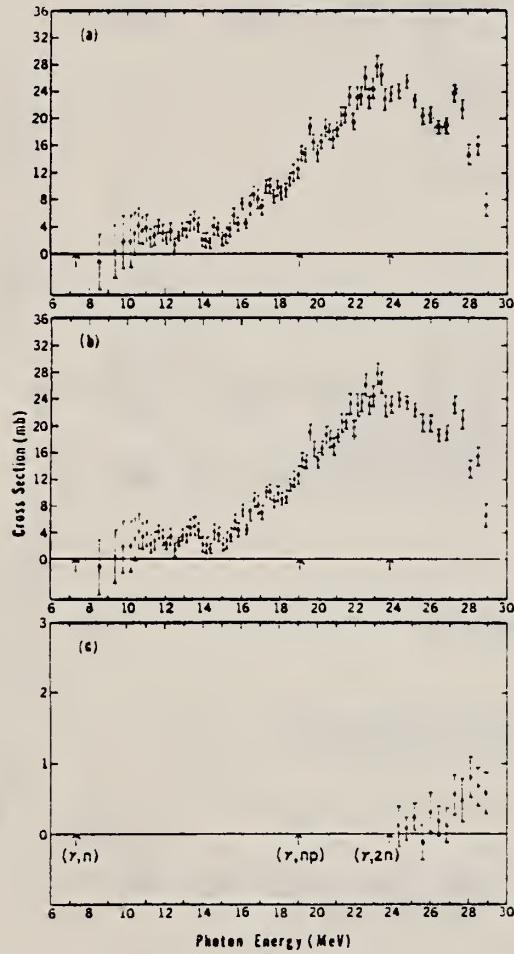


FIG. 3. Cross sections for  $^{25}\text{Mg}$ . (a) Total photoneutron cross section,  $\sigma[(\gamma, n) + (\gamma, np) + (\gamma, 2n)]$ . (b) Single-photoneutron cross section,  $\sigma[(\gamma, n) + (\gamma, np)]$ . (c) Double-photoneutron cross section,  $\sigma(\gamma, 2n)$ .

TABLE II. Integrated total photoneutron cross sections and their moments.

Nucleus	$E_{\gamma\max}$ (MeV)	$\sigma_{int}^a$ (MeV mb)	$\sigma_{-1}^b$ (mb)	$\sigma_{-2}^b$ (mb MeV <sup>-1</sup> )
$^{23}\text{Na}$	27	119	5.74	0.288
$^{25}\text{Mg}$	29	249	11.7	0.584

$$^a \sigma_{int} = \int_{E_{thr}}^{E_{\gamma\max}} \sigma_{tot} dE.$$

$$^b \sigma_{-n} = \int_{E_{thr}}^{E_{\gamma\max}} \sigma_{tot} E^{-n} dE.$$

(over)

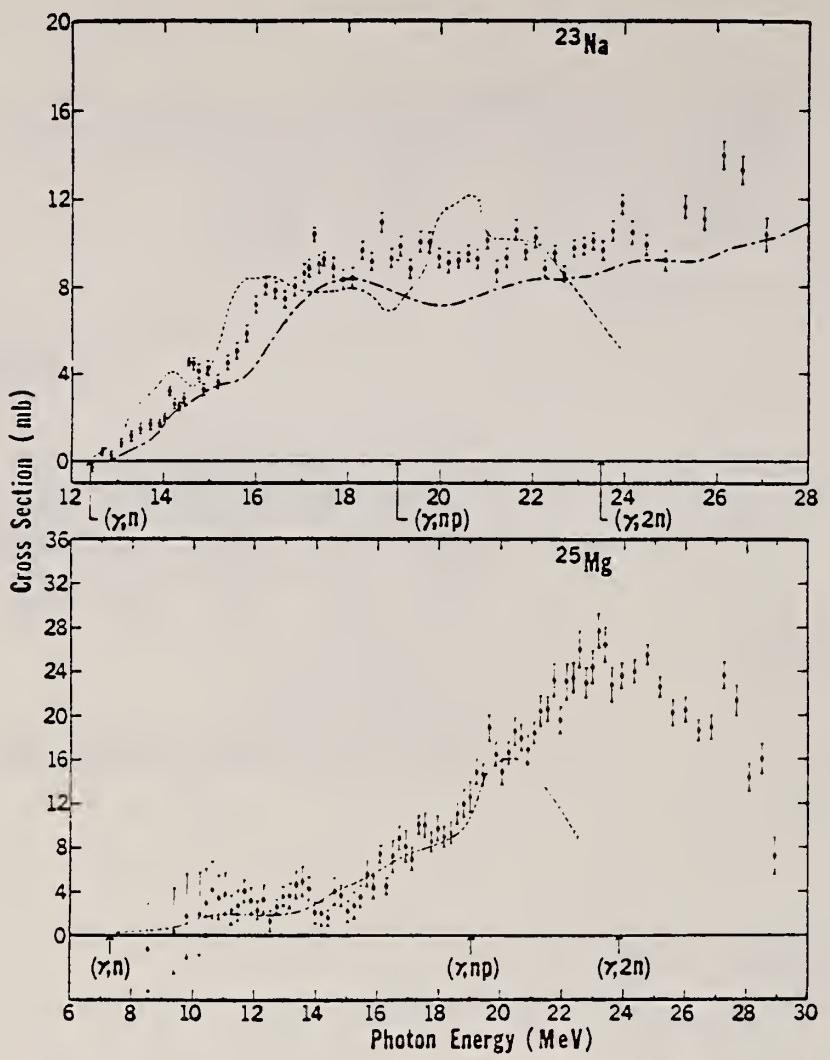


FIG. 4. Comparison of the present total photonutron cross sections with previous measurements. The dashed curves indicate the results of Sato (Ref. 11) for  $^{23}\text{Na}$  and of Nathans and Yergin (Ref. 13) for  $^{25}\text{Mg}$ , the dash-dot curve represents the  $^{23}\text{Na}$  data of Fielder, Bolen, and Whitehead (Ref. 12).

ELEM. SYM.	A	Z
Mg	25	12

METHOD

REF. NO.

71 Ba 2

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N	ABX	7 - 11	C	8,11	TOF-D		135
		(7.3-11.0)					

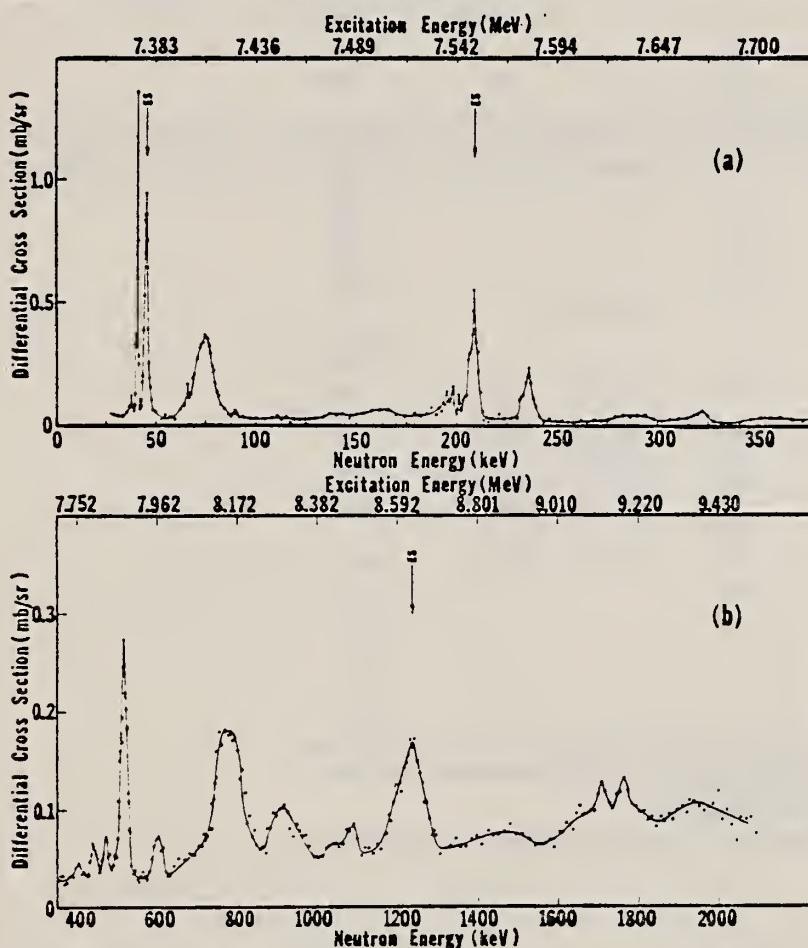


FIG. 16. The 135° differential threshold photoneutron cross section for  $^{25}\text{Mg}$  (see caption to Fig. 4).

FIG. 4. The 135° differential threshold photoneutron cross section for  $^{207}\text{Pb}$  at low energies versus the energy of the emitted neutron (lower scale) and the excitation energy (upper scale). The arrows indicate peaks which decay to excited states of the residual nucleus (ES), or peaks owing to contaminating isotopes in the photoneutron sample. The inset shows the  $^{207}\text{Pb}(\gamma, \pi)$  cross section averaged with a square 40-keV wide smoothing function.

Also see:

R. J. Baglan et al.  
Phys. Rev. C3, 2475  
(1971)

[over]

TABLE VII. Resonance parameters for  $^{24,25,26}\text{Mg}$ ,  $^{19}\text{F}$ , and  $^{31}\text{P}$ . For all resonances, the area under the peak in the  $135^\circ$  differential cross section is multiplied by  $4\pi$  to yield approximate values for  $g_\gamma \Gamma_{\gamma_0} \Gamma_s / \Gamma \approx g_\gamma \Gamma_{\gamma_0}$ . For those resonances where  $J^\pi$  is known, the differential area is multiplied by the appropriate factor  $F$  from Table I to obtain  $\Gamma_{\gamma_0}$ .  $E_L$  is the laboratory neutron energy for the  $(\gamma, n)$  reaction and  $E_n$  is the corresponding laboratory neutron energy for a neutron-induced reaction. Column 5 labels the peak as a ground-state (GS) or excited-state (ES) transition as determined in this work alone.

Nucleus	$E_L$ (keV)	$E_n$ (MeV)	$g_\gamma \Gamma_{\gamma_0} \Gamma_s / \Gamma$ (eV)	GS or ES	$J^\pi$	$\Gamma_{\gamma_0}$ (eV)	$E_n$ (keV) (This work)
$^{24}\text{Mg}$	22	16.559	0.61	GS	$(1^-)$	0.40	28
	55	16.596	2.4		$(1^-)$	1.6	66
	110	16.656	4.0		$(1^-)$	2.7	128
	312	16.871	10.7		$(1^-)$	7.1 <sup>a</sup>	354
	382	16.95					432
	717	17.30	19.5		$(1^-)$	13.0 <sup>a</sup>	804
	1210	17.83					1348
	1620	18.26					1799
	1955	18.61					2168
							46.8
$^{25}\text{Mg}$	41.1	7.374	0.09	GS			
	45.1	8.746	0.31				
	74.9	7.410	0.36		$\frac{1}{2}^-$ <sup>b</sup>	1.1	84.1 <sup>b</sup>
	208	8.920	0.29				261
	236	7.580	0.09				445
	404	7.756	0.03				484
	439	7.793	0.05		$\frac{3}{2}^+$ <sup>c</sup>		520
	472	7.828	0.06				567
	515	7.873	0.46		$\frac{3}{2}^+$ <sup>c</sup>		661
	601	7.964	0.18				857
	781	8.152	1.51				1003
	912	8.292	0.72				1869
	1236	9.999	2.4 <sup>c</sup>		$\frac{3}{2}^+$ or $\frac{5}{2}^+$ <sup>c</sup>		1931
	1707	9.12					
	1764	9.18					
$^{26}\text{Mg}$	54.3	11.155	2.6	GS	$1^-(1^+, 2^+)$	1.75	62.3
	63.2	11.164	0.05			0.034	72.2
	181	11.289	1.0		$1^-(1^+, 2^+)$	0.68	202
	222	11.333	1.9		$1^-(1^+, 2^+)$	1.3	248
	391	11.511	5.1		$1^-(1^+, 2^+)$	3.5	433
	621	11.753	32.5		$1^-(1^+, 2^+)$	22.2	684
	738		15.0 <sup>d</sup>		ES	5.1	
	1122	12.279	14.7		$1^-(1^+, 2^+)$	10.0	1232
$^{19}\text{F}$	100	10.542	1.8	GS			118
$^{31}\text{P}$	109	12.429	0.86				121
	280	12.609	0.60				307
	398	12.732	0.59				434
	678	13.026	0.90				737
	939	13.297	4.4				1018

<sup>a</sup>These values for  $\Gamma_{\gamma_0}$ , when increased by approximately a factor of 2 in order to include the relatively high cross sections in the valleys, agree very well with corresponding values from Ref. 8 (see Ref. 4).

<sup>b</sup>This resonance was seen at  $E_n = 83$  and 84 keV in Refs. 24 and 25, respectively.

<sup>c</sup>Analogs of states in  $^{24}\text{Na}$  (see text). The value for  $g_\gamma \Gamma_{\gamma_0} \Gamma_s / \Gamma$  given in Ref. 26 was not corrected with the multiplicative factor in Table II.

<sup>d</sup>Assuming a first-excited-state transition.

<sup>4</sup>R.L. Van Hemert, C.D. Bowman, R.J. Baglan, and B.L. Berman (to be published); R.L. Van Hemert, University of California Lawrence Radiation Laboratory Report No. UCRL-50442, 1968 (unpublished).

<sup>8</sup>S.C. Fultz, M.A. Kelly, J.T. Caldwell, R.R. Harvey, and B.L. Berman, Bull. Am. Phys. Soc. 14, 103 (1969), and private communication.

<sup>24</sup>H.W. Newson, R.C. Block, P.F. Nichols, A. Taylor, A.K. Furr, and E. Merzbacher, Ann. Phys. (N.Y.) 8, 211 (1959).

<sup>25</sup>D.J. Hughes and R.B. Schwartz, Neutron Cross Sections (U.S. Government Printing Office, Washington, D.C., 1966), 2nd ed., 2nd Suppl., Vol. IIc.

REF.

B. L. Berman and T. W. Phillips  
 Phys. Rev. C6, 2295 (1972)

ELEM. SYM. A

Mg

25

12

METHOD

REF. NO.

72 Be 9

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, N	NOX	7 (7.864)	C	UKN	TOF-D		90

Repeat of previous experiment.

SEE 70BES

The location in  $^{23}\text{Mg}$  of the isobaric analog of the first excited state of  $^{25}\text{Na}$  has been measured to be  $7864.5 \pm 1.2$  keV. Combining this result with other data yields a value for the coefficient of the cubic term in the isobaric-multiplet mass equation of  $-0.2 \pm 4$  keV.

REF.  
 E. W. Lees, C. S. Curran, S. W. Brain, W. A. Gillespie,  
 A. Johnston, R. P. Singhal  
 J. Phys. G1, L13 (1975)

ELEM. SYM.	A	Z
Mg	25	12

METHOD

REF. NO.
75 Le 3

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	LFT	0- 4	D	62-119	MAG-D		DST

1.611, 3.405 MEV

Abstract. The members of the ground state band of  $^{25}\text{Mg}$  have been studied in the momentum transfer range 0.2 to  $1.15\text{ fm}^{-1}$ . The reduced transition probabilities and transition radii were measured for the 1.612 MeV and 3.405 MeV levels. The transition probabilities are shown to be considerably more precise than existing measurements and are compared with various theoretical predictions. The hexadecupole strength to the  $\frac{5}{2}^+$  levels is also discussed.

Table 1. Best fit DWBA parameters.

$E_x$ (MeV)	$c_{tr}$ (fm)	$t_{tr}$ (fm)	$R_{tr}\dagger$ (fm)	$B(E2,\uparrow)\ddagger$ ( $e^2 \text{ fm}^4$ )	$\chi^2 \text{ pdf}\S$
$1.611 \pm 0.004$	$2.85 \pm 0.20$	$2.21 \pm 0.23$	$4.25 \pm 0.11$	$158 \pm 7$	1.0
$3.405 \pm 0.007$	$2.48 \pm 0.43$	$2.42 \pm 0.32$	$4.28 \pm 0.18$	$57 \pm 4$	0.7

$\dagger R_{tr}$  is the transition radius.

$\ddagger B(E2,\uparrow)$  is the E2 reduced transition probability from the ground state.

$\S \chi^2 \text{ pdf}$  is  $\chi^2$  per degree of freedom.

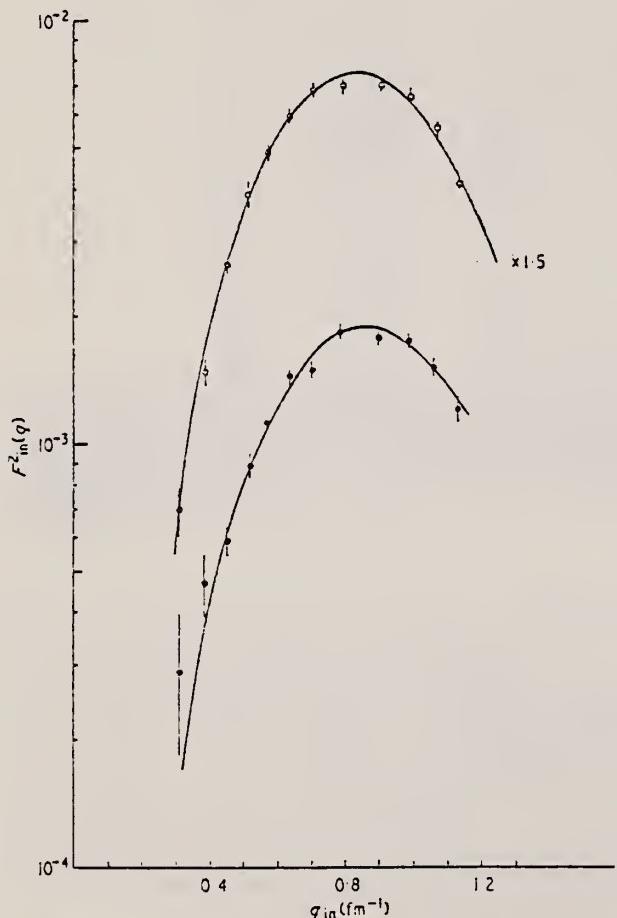


Table 2. Comparison of  $B(E2,\uparrow)$  deduced from lifetime measurements and present results. See text for references to individual measurements.

$E_x$ (MeV)	$J^\pi$	Lifetime (fs)	Mixing ratio	Ground state branching ratio	
				$B(E2,\uparrow)$ ( $e^2 \text{ fm}^4$ )	$B(E2,\uparrow)\text{e}, e'$ ( $e^2 \text{ fm}^4$ )
1.612	$\frac{7}{2}^+$	$20.6 \pm 2.6^a$	$0.20 \pm 0.02$	100%	$187 \pm 43$
		$24.5 \pm 3.3^b$	$0.20 \pm 0.02$	100%	$157 \pm 37$
3.405	$\frac{5}{2}^+$	$10 \pm 5$	0	$13 \pm 1\%$	$54 \pm 27$
					$57 \pm 4$

<sup>a</sup> Includes the measurement by Fagg *et al* (1969).

<sup>b</sup> Excludes the measurement by Fagg *et al* (1969).

Phys. Rev. 187, 1384 (69)

Figure 1. Inelastic form factors for the  $\frac{5}{2}^+$  level in  $^{25}\text{Mg}$  at 1.612 MeV ( $\circ$ ) and for the  $\frac{3}{2}^+$  level at 3.405 MeV ( $\bullet$ ). The full curves are the corresponding best-fit DWBA Coulomb form factors for an  $L = 2$  transition. The upper curve is multiplied by a scale factor of 1.5. See text for further details.

REF.

K. Bangert, U.E.P. Berg, G. Junghans, R. Stock, K. Wienhard,  
 H. Wolf  
*Nucl. Phys. A261*, 149 (1976)

ELEM. SYM.	A	Z
Mg	25	12

METHOD

REF. NO.

76 Ba 2

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,P	ABX	14- 18	C	19- 29	TEL-D		90
G,A	ABX	18- 24	C	29	TEL-D		90
G,D	ABX	19- 24	C	29	TEL-D		90
G,PG	ABY	13- 29	C	19- 29	SCD-D		90
G,NG	ABY	8- 29	C	19- 29	SCD-D		90

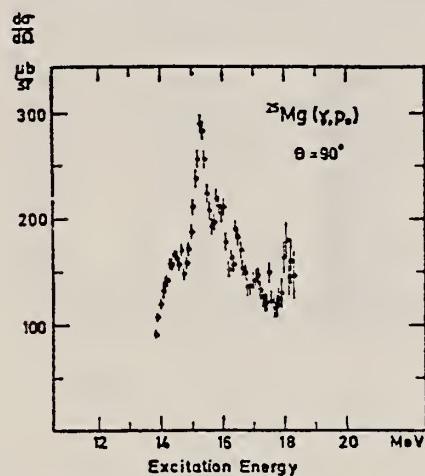


Fig. 6. The  $90^\circ$   $^{25}\text{Mg}(\gamma, p_0)$  differential cross section as derived from the 18.5 MeV proton spectrum, assuming ground-state transitions.

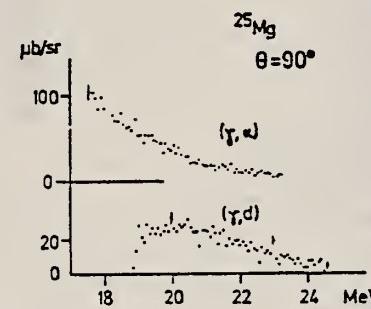


Fig. 7. The  $90^\circ$   $^{25}\text{Mg}(\gamma, d)$  and  $^{25}\text{Mg}(\gamma, \alpha)$  differential cross sections derived from the 28.7 MeV particle spectra.

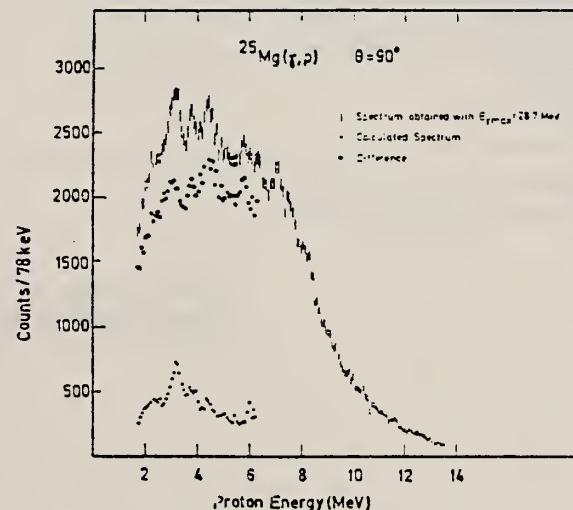


Fig. 8. A comparison between the 28.7 MeV  $^{25}\text{Mg}$  photoproton spectrum and a " $(\gamma, p_0)$ " spectrum derived from the  $^{25}\text{Mg}(\gamma, p_0)$  differential cross section of fig. 6.

(over)

TABLE 4

Results of the  $^{23}\text{Mg}(\gamma, xy)$  experiment, giving the "bremsstrahlung-weighted" integrated cross sections in MeV · mb for the population of excited residual nuclear states

	Bremsstrahlung endpoint energy (MeV)		
	18.5	21.0	28.7
<i>(a) <math>^{24}\text{Na}</math> states</i>			
g.s.      4 <sup>+</sup>			
472 keV, 1 <sup>+</sup>	?	?	?
563 keV, 2 <sup>+</sup>	?	?	?
1341 keV, 2+1347 keV, 1 <sup>+</sup>		0.89	6.09
1345 keV, 3		0.52	2.20
1511 keV, (3, 5) <sup>+</sup>		0.33	2.21
1885 keV, (2, 3) <sup>+</sup>		0.41	3.72
2513 keV, (1-3)		0.15	1.25
2561 keV, (1-4) <sup>+</sup>		0.49	3.67
2909 keV, 3 <sup>+</sup>		0.28	1.15
<i>(b) <math>^{24}\text{Mg}</math> states</i>			
g.s.      0 <sup>+</sup>	13.04 <sup>a)</sup>	24.9 <sup>a)</sup>	?
1369 keV, 2 <sup>+</sup>	4.30	4.76	12.84
4123 keV, 4 <sup>+</sup>	1.32	2.12	5.18
4239 keV, 2 <sup>+</sup>	1.04	1.34	3.64
5236 keV, 3 <sup>+</sup>	0.82	0.93	2.65
6010 keV, 4 <sup>+</sup>	0.55	0.58	1.56
7616 keV, 3 <sup>-</sup>	0.18	0.42	1.63
8436 keV, 4 <sup>+</sup>	0.29	1.03	2.94
9515 keV, 4 <sup>+</sup> $T = 1$		0.78	2.84
9827 keV, 1 <sup>+</sup> $T = ?$		0.29	1.28
9967 keV, 1 <sup>+</sup> $T = 1$		0.55	1.05
10059 keV, (1, 2) <sup>+</sup> $T = 1$		0.32	1.38
10822 keV, ?			1.42
<i>(c) <math>^{23}\text{Na}</math> states</i>			
404 keV, $\frac{1}{2}^+$	?	?	?
2076 keV, $\frac{7}{2}^+$			3.11
<i>(d) <math>^{21}\text{Ne}</math> states</i>			
350 keV, $\frac{1}{2}^+$	?	?	?
1746 keV, $\frac{7}{2}^+$			<1.32
Sum of observed ( $\gamma, p$ ) excited states cross sections		3.07	20.29
Sum of observed ( $\gamma, n$ ) excited states cross sections	8.5	13.12	38.42
Proton yield		12.15	77.10
$(\gamma, n) + (\gamma, np)$ yield <sup>a)</sup>	21.54	38.02	106.11

Bremsstrahlung spectra are normalized at 11.44 MeV.

<sup>a)</sup> Calculated from the data of ref. <sup>2)</sup>.

<sup>2</sup>S.C. Fultz et al., Phys. Rev. C4, 149 (1971);  
R.A. Alvarez et al., Phys. Rev. C4, 1673 (1971).

REF.

E. W. Lees, C. S. Curran, T. E. Drake, W. A. Gillespie,  
A. Johnston, and R. P. Singh  
J. Phys. (London) G2, 341 (1976)

ELEM. SYM.	A	Z
Mg	25	12

METHOD

REF. NO.

76 Le 3

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	FMF	1- 4	D	62-119	MAG_D		DST

Table 3. Results for the DWBA analysis of the present data using an  $L = 2$  transition within the framework of the Tassie model. The accepted values have been used for the excitation energies, spins and parities of the states.

7 LEVELS, .98-4.1 MEV

$E_x$ (MeV)	$J^\pi$	$g_{tr}$ (fm)	$r_{tr}$ (fm)	$R_{tr}$ (fm)	$B(E2, \uparrow)$ ( $e^2 \text{ fm}^4$ )
0.975	$\frac{1}{2}^+$	2.85†	2.21†	4.25†	$2.3 \pm 0.6$
1.612	$\frac{1}{2}^+$	$2.85 \pm 0.20$	$2.21 \pm 0.23$	$4.25 \pm 0.11$	$156 \pm 7$
1.965	$\frac{3}{2}^+$	2.85†	2.21†	4.25†	$3.0 \pm 0.5$
2.563	$\frac{1}{2}^+$	2.45	2.21†	4.01	$4.3 \pm 0.8$
2.801	$\frac{3}{2}^+$	2.45†	2.21†	4.01†	$5.3 \pm 0.4$
3.405	$\frac{3}{2}^+$	$2.48 \pm 0.43$	$2.42 \pm 0.32$	$4.28 \pm 0.18$	$57 \pm 4$
4.059	$\frac{3}{2}^+$	2.66	2.21†	4.13	$9.6 \pm 1.0$

† Denotes that the radial parameter for this level was fixed.

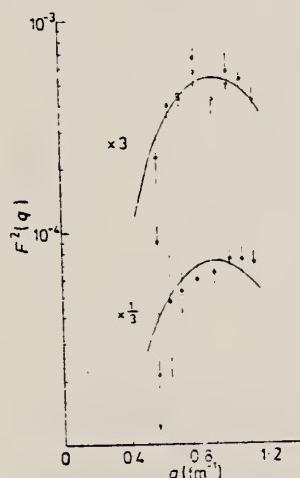


Figure 4. Inelastic form factors for the transitions in  $^{25}\text{Mg}$  to the levels at 2.564 MeV (○) and 2.801 MeV (●). The full curves are the corresponding best-fit  $L = 2$  Coulomb form factors calculated in DWBA. The upper curve and data are multiplied by a scale factor of 3 and the lower ones by  $\frac{1}{3}$ .

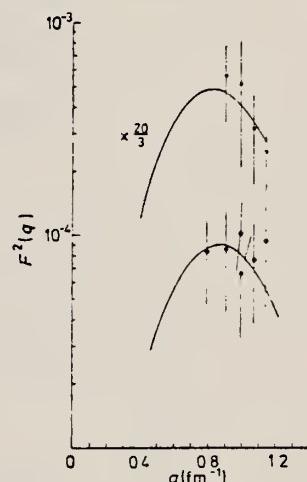


Figure 3. Inelastic form factors for the transitions in  $^{25}\text{Mg}$  to the levels at 0.975 MeV (○) and 1.965 MeV (●). The full curves are the corresponding best-fit  $L = 2$  Coulomb form factors calculated in DWBA. The upper curve and data are multiplied by a scale factor of  $\frac{20}{3}$ .

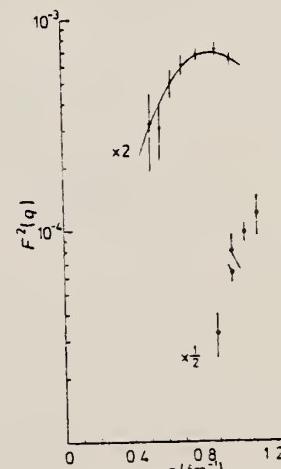


Figure 5. Inelastic form factors for the transitions in  $^{25}\text{Mg}$  to the levels at 4.059 MeV (○) and 5.252 MeV (●). The full curve is the corresponding best-fit  $L = 2$  Coulomb form factor calculated in DWBA. The upper curve and data are multiplied by a scale factor of 2 and the lower data by  $\frac{1}{2}$ .



METHOD			REF. NO.			
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE	
			TYPE	RANGE	TYPE	RANGE
G,P	ABY	12-68	C	30-68	ACT	4PI

Analysis is made of reactions interfering with photon activation analysis procedures.

The activation yield curves have been presented for a number of photonuclear reactions in the energy range from 30 to 68 MeV, in order to evaluate quantitatively the interferences due to competing reactions in multielement photon activation analysis. The general features of the yields as functions of both target mass number and excitation energy were elucidated from the data obtained, discussion being given on the results in terms of the reaction mechanism.

Simultaneous neutron activation due to appreciable neutron production from the converter and surrounding materials has also been studied, and, finally, the magnitudes of interferences in real multielement analysis were given in the form of their energy dependences.

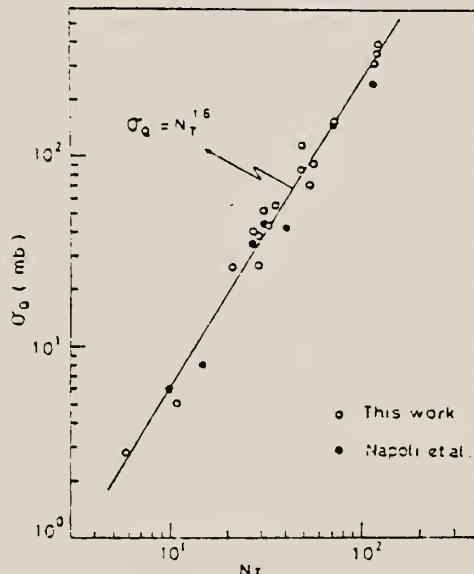


Fig. 2. Yield per equivalent quanta versus target neutron number.

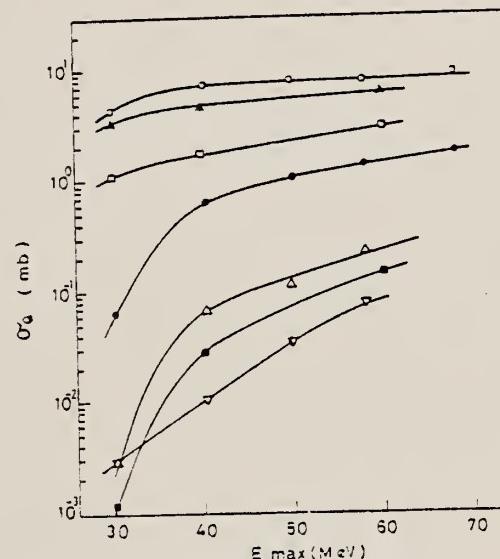


Fig. 3. Activation yield curves for the reactions on C, Na, Mg and Al.  
 —  $^{12}\text{C}(\gamma, n)^{11}\text{C}$ , □  $^{12}\text{C}(\gamma, \text{zn})^7\text{Be}$ , ▲  $^{23}\text{Na}(\gamma, n)^{22}\text{Na}$ ,  
 ○  $^{25}\text{Mg}(\gamma, p)^{24}\text{Na}$ , ●  $^{24}\text{Mg}(\gamma, pn)^{22}\text{Na}$ , Δ  $^{27}\text{Al}(\gamma, \text{zn})^{22}\text{Na}$ ,  
 -  $^{27}\text{Al} - ^{24}\text{Na}$ .

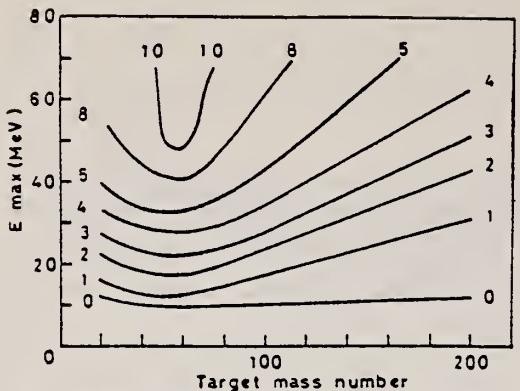


Fig. 10. Yields of the  $(\gamma, p)$  reactions as a function of bremsstrahlung maximum energy and target mass number. The numerical values in the figure are yields per equivalent quanta in mb.





MG  
A=26

M<sub>IG</sub>  
A=26

MG  
A=26



Elem. Sym.	A	Z
Mg	26	12

Method

Van de Graaff; 1.83 MeV  $\gamma$  source by  $Mg^{26}(p, p'\gamma)$  with 4.4 MeV protons;  
 ring scatterer; NaI.

Ref. No.

61 Ra 1

JHH

Reaction	E or $\Delta E$	$E_0$	$\Gamma$	$\int \sigma dE$	$J\pi$	Notes
$(\gamma, \gamma)$	1.83	1.83				Mean life = $(7 \pm 3) \times 10^{-13}$ sec.

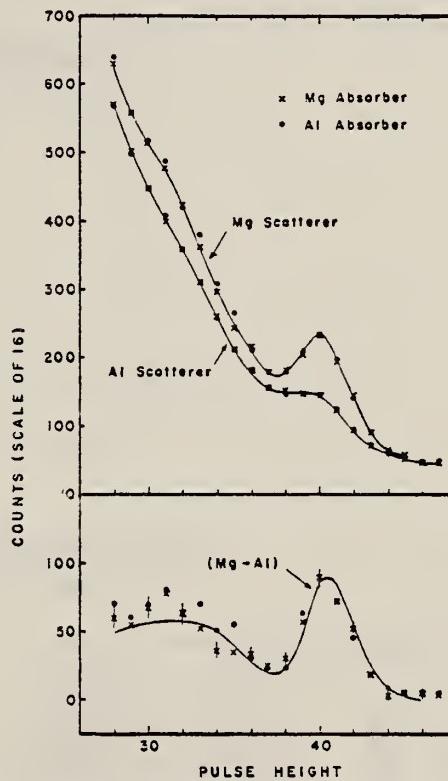


FIG. 6. Resonant scattering of the 1.83-Mev  $\gamma$  ray from  $Mg^{26}$ . The upper curves give the original data for the scatterer-absorber combinations noted. Statistical errors can be estimated from the left-hand scale which gives the total number of counts for each point. Mg scatterer-Al scatterer differences are shown in the lower plots, where the solid curve is that obtained when the counter is exposed to direct radiation from the target. The sum of counts for pulse heights 39 to 42 was taken to represent the resonance effect.

REF. E. C. Booth, B. Chasan and K. A. Wright  
Nucl. Phys. 57, 403-420 (1964)

ELEM. SYM.	A	Z
Mg	26	12

METHOD

Van de Graaff; resonance fluorescence

REF. NO.	NVB
64 Bo 1	

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,G	LFT	1-3 (0.5 - 3.0)	C	1 - 3 (0.5 - 3.0)	NAI-D		100

ABI

TABLE I  
Cases of observed resonance fluorescence

Nucleus multipol.	State (MeV)	Spin	$\Gamma_0/\Gamma^*$	$T(gw\Gamma_0^*/\Gamma^*)^{-1}$ (sec.)	Mean lifetime $T$ BCW (sec)	Mean lifetime $T$ other (sec)	Ref.	$\Gamma_0/\Gamma_w$ BCW
Mg <sup>24</sup>	0.00	0 <sup>+</sup>						
E2	1.83	2 <sup>+</sup>	1	$12 \pm 5 \times 10^{-14}$	$37 \pm 15 \times 10^{-14}$	$70 \pm 30 \times 10^{-14}$	11) 22	

METHOD

REF. NO.

66 Ti 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,E/	LFT	7-15	D	51	MAG-D	36-51	DST

Angular distribution measured for  $q = 0.48, 0.41, 0.32 \text{ fm}^{-1}$ .

DST CONST 0

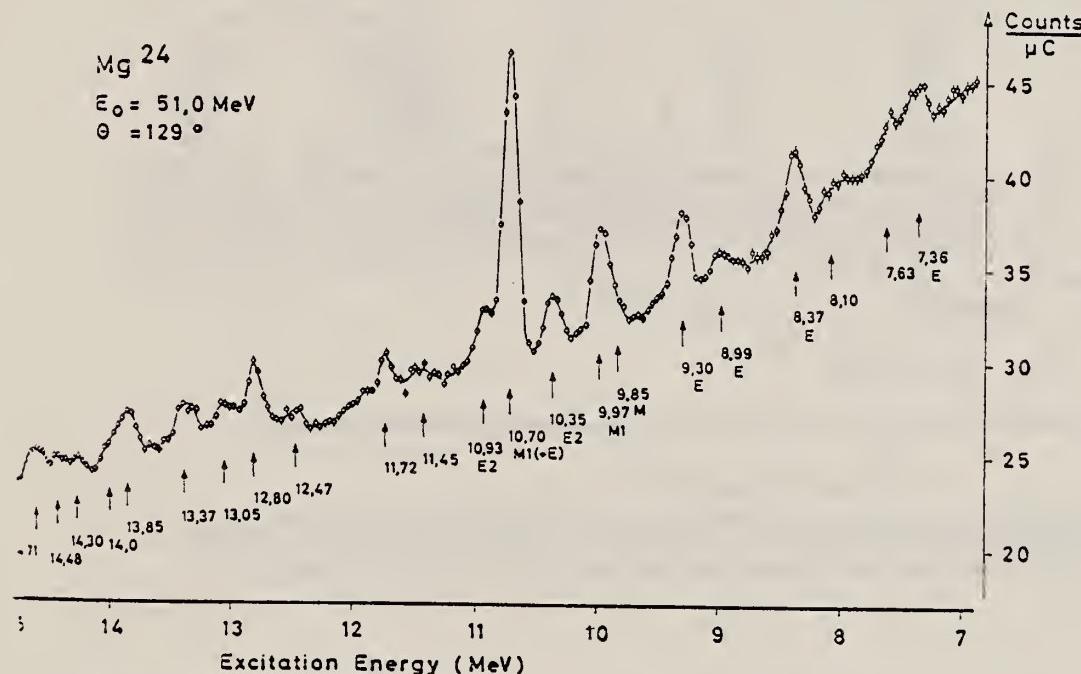


Fig. 1. Spectrum of inelastically scattered electrons from  $^{24}\text{Mg}$ . The effective target thickness was  $50 \text{ mg/cm}^2$ . The arrows indicate the measured excitation energies in MeV. The type of transition [electric (E) or magnetic (M)] is labeled. Note the suppressed zero of the ordinate scale. The elastic peak has a height of  $2.4 \times 10^4$  units of the ordinate scale.

$E_x$ (MeV)	$\Gamma_\gamma^\alpha$ (eV)	$\Gamma_\gamma^\alpha/\Gamma_W$	$R_{tr}$ (fm)
$9.85 \pm 0.04$	$7.95 \pm 1.2$	0.38	$3.50 \pm 0.49$
$9.97 \pm 0.03$	$0.24 \pm 0.05$	0.58	$5.05 \pm 0.50$
$10.35 \pm 0.03$	$22.2 \pm 2.4$	0.86	$3.60 \pm 0.36$
$10.70 \pm 0.03$	$0.26 \pm 0.11^*$	0.50	—
$10.93 \pm 0.04$			

\* Calculated with  $R_{tr}$  from 10.35 MeV transition.

Table 1. Results for  $^{24}\text{Mg}$ . The first two columns give excitation energies and multipolarities as determined from this work. Column 3 to 5 show the ground state radiation widths  $\Gamma_\gamma^\alpha$ , the transition strengths in Weisskopf units  $\Gamma_W$  and the transition radii  $R_{tr}$ . The Bonn approximation has been used.

[over]

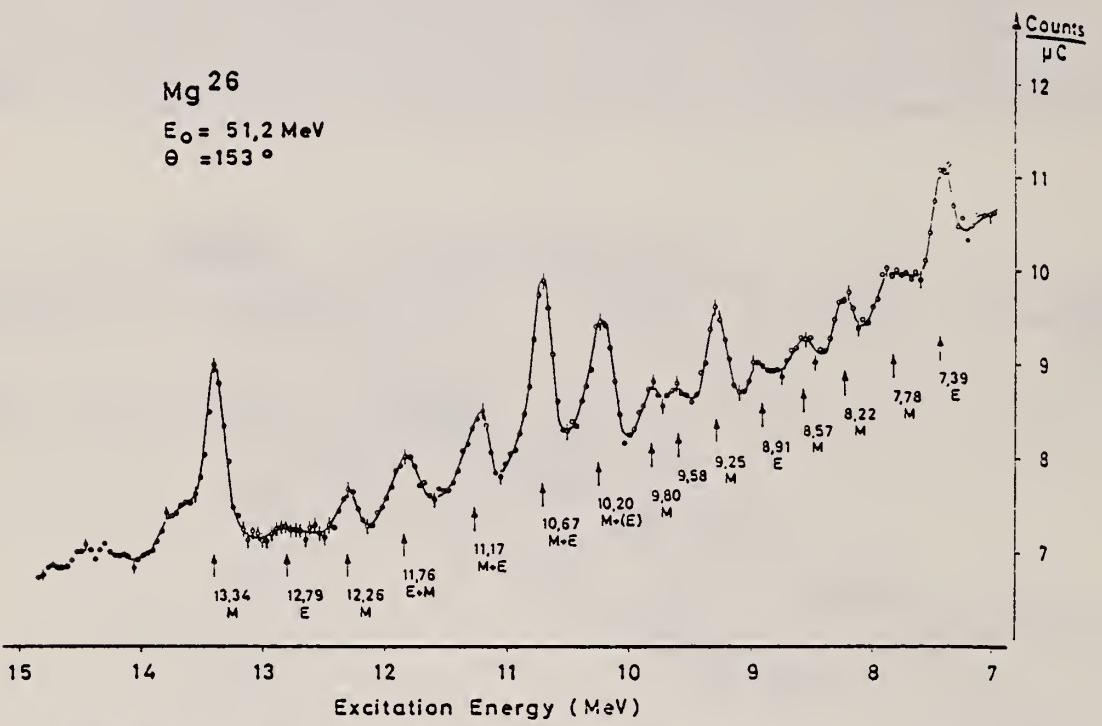


Fig. 2. Spectrum of inelastically scattered electrons from  $^{26}\text{Mg}$ . The effective target thickness was  $170 \text{ mg/cm}^2$ . The arrows indicate the measured excitation energies in MeV. The type of transition [electric (E) or magnetic (M)] is labeled. Note the suppressed zero of the ordinate scale. The elastic peak has a height of  $2.5 \times 10^3$  units of the ordinate scale.

REF.

H. W. Kuehne, P. Axel, and D. C. Sutton  
 Phys. Rev. 163, 1278 (1967)

ELEM. SYM.	A	Z
Mg	26	12

METHOD

REF. NO.

67 Ku 2

HMG

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, G	LFT	10	D	10	NAI-D	10	135

Photons, defined in energy to about 1% with the aid of a bremsstrahlung monochromator, were scattered by isolated energy levels in C, Mg, and Si. Parameters for the six observed levels are:

Isotope	Energy (MeV)	$\Gamma_0/\Gamma$ (eV)	$\Gamma_0/\Gamma$	$B(M1)/(e\hbar/2M_p c)^2$
C <sup>18</sup>	15.11	36	1	0.93
Mg <sup>24</sup>	10.66±0.02	14	0.8	1.21
Si <sup>28</sup>	11.42±0.02	23	1	1.33
Si <sup>28</sup>	12.33±0.03	-	-	-
Mg <sup>24</sup>	9.92±0.03	3.0	0.5	0.49
Mg <sup>24</sup>	10.07±0.05	4.2	-	≥0.36

The 15.11-MeV level in C<sup>18</sup>, the 9.92- and 10.66-MeV levels in Mg<sup>24</sup>, and the 11.42-MeV level in Si<sup>28</sup> are  $T=1$ ,  $T_z=0$  analogs of low-lying 1+ states in the neighboring odd-odd nuclei. These levels exhaust most of the magnetic dipole transition strength of the respective nuclei, and therefore give information about the expectation value of l-s in the ground state.

ELEM. SYM.	A	Z
Mg	26	12

METHOD

REF. NO.	HMG
68 Be 2	

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	ABX	8-14	D	39, 56	MAG-D		180

TABLE I. Levels at 8 to 14 MeV in  $^{26}\text{Mg}$  found in electron scattering. The differential cross sections are in units of  $10^{-34} \text{ cm}^2$  per sr.

Energy (MeV)	Parameters as M1 transitions					Energy and type, Titze and Spamer*
	$(d\sigma/d\Omega)_{56 \text{ MeV}}$	$(d\sigma/d\Omega)_{39 \text{ MeV}}$	$R$ (fm)	$\Gamma_0$ (eV)		
8.52 $\pm$ 0.05	81 $\pm$ 22	159 $\pm$ 57	$3.2_{-1.4}^{+0.6}$	$0.5_{-0.2}^{+0.4}$		8.22 M 8.57 M
9.24 $\pm$ 0.03	268 $\pm$ 26	695 $\pm$ 63	$3.62_{-0.19}^{+0.17}$	$3.3_{-0.7}^{+0.9}$		8.91 E
9.67 $\pm$ 0.05	246 $\pm$ 26	409 $\pm$ 69	$2.90_{-0.54}^{+0.36}$	$1.7_{-0.6}^{+0.8}$		9.25 M
10.18 $\pm$ 0.03	447 $\pm$ 30	968 $\pm$ 77	$3.40_{-0.18}^{+0.16}$	$5.7_{-1.2}^{+1.3}$		9.58, 9.80 M
10.63 $\pm$ 0.03	593 $\pm$ 42	1332 $\pm$ 77	$3.47 \pm 0.14$	$9.1_{-1.7}^{+2.0}$		10.20 M + (E)
11.20 $\pm$ 0.05	274 $\pm$ 26	525 $\pm$ 68	$3.23_{-0.33}^{+0.26}$	$3.9_{-1.1}^{+1.3}$		10.67 M + E
11.67, 11.82						11.17 M + E
12.31	62 $\pm$ 26	<97	<3.8	<1.2		11.76 E + M 12.26 M
13.33 $\pm$ 0.03	689 $\pm$ 35	1174 $\pm$ 90	$3.10_{-0.21}^{+0.17}$	$14.5_{-3.0}^{+3.3}$		12.79 E
13.66 $\pm$ 0.06	110 $\pm$ 31	180 $\pm$ 76	$3.0_{-1.0}^{+0.8}$	$2.3_{-1.5}^{+2.4}$		13.34 M

\* See Ref. 10.

<sup>10</sup> O. Titze and E. Spamer, Z. Naturforsch. 21a, 1504 (1966).

Mg	26	12
REF. NO.	69 Be 3	egf
		<u>949</u>

O = 10 to 1200 KEV

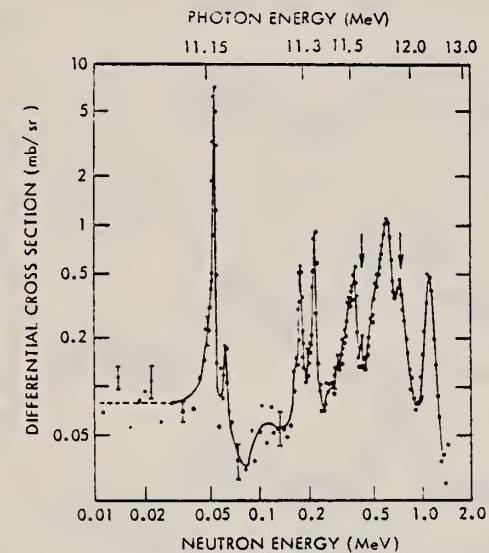


FIG. 1. Threshold photoneutron cross section for  $\text{Mg}^{26}$  at  $135^\circ$  as a function both of photon energy and of laboratory neutron energy. The solid line drawn through the data points is to guide the eye. The arrows indicate excited-state transitions. The electron beam energy was 13.3 MeV.



METHOD

REF. NO.

70 Go 3

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	ABX	15-26	D	45-55	MAG-D		DST

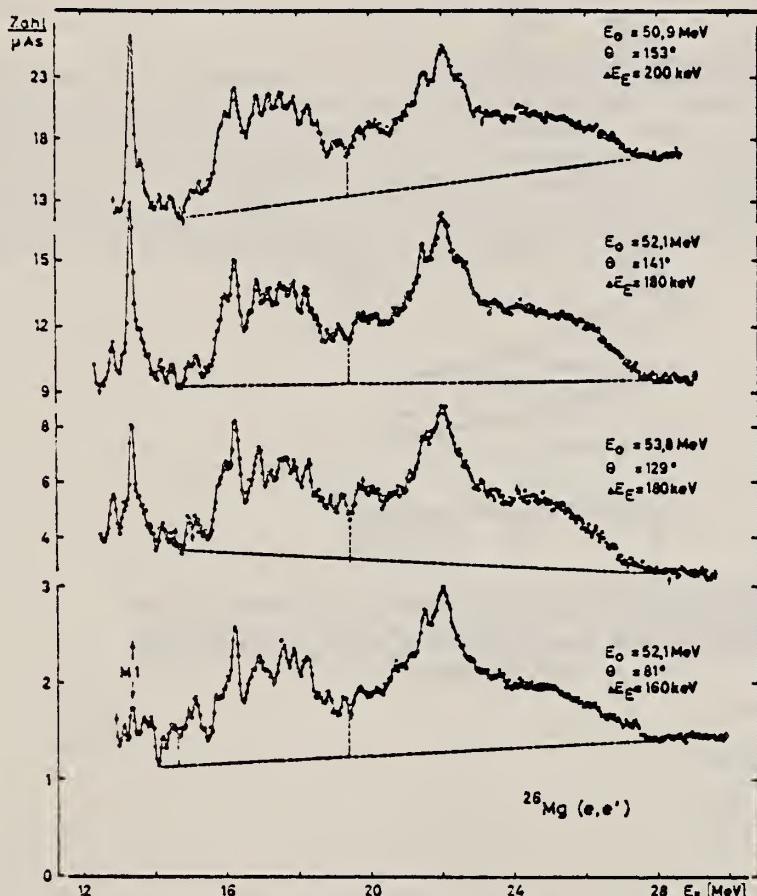


Fig. 3. Riesenresonanz von  $^{26}\text{Mg}$ . Die von den Meßspektren bereits subtrahierten Anteile sind in Tabelle I zusammengestellt. Die gestrichelten Linien geben den zur Auswertung angenommenen Untergrund und die Integrationsgrenzen an. Alle Spektren sind auf gleiche elastische Fläche  $A_E = 5,0 \cdot 10^3 \text{ MeV}/\mu\text{As}$  normiert

[over]

Tabelle 3. Ergebnisse an  $^{26}\text{Mg}$ . Bei allen Werten ist  $A_F = 5,0 \cdot 10^3 \text{ MeV}/\mu\text{As}$ . Die Flächen  $A_I$  wurden jeweils in den Bereichen 14,5 bis 19,5 MeV („ $E_x = 17 \text{ MeV}''$ ) und 19,5 bis 28,0 MeV („ $E_x = 22 \text{ MeV}''$ ) integriert. Bezuglich der Strahlungskorrekturen siehe Unterschrift zu Tabelle 2

$E_0$ [MeV]	$\theta$ [Grad]	$E_x$ [MeV]	$q^2$ [fm $^{-2}$ ]	$A_I$ [MeV/ $\mu\text{As}$ ]	$G$ [10 $^{-6}$ ] <sup>a</sup>	$B(C1, q)$ [fm $^2$ ]
50,9	153	17	0,180	28,3	1,31	0,72
		22	0,155	45,8	2,51	1,05
52,1	141	17	0,180	13,9	1,38	0,54
		22	0,155	27,9	3,22	1,07
53,8	129	17	0,180	11,3	1,94	0,54
		22	0,155	18,2	3,63	0,91
52,1	81	17	0,087	3,2	3,55	0,65
		22	0,080	5,5	7,31	1,30

<sup>a</sup>  $G = (d\sigma/d\Omega)_t (k_t^2/V_T)$ .

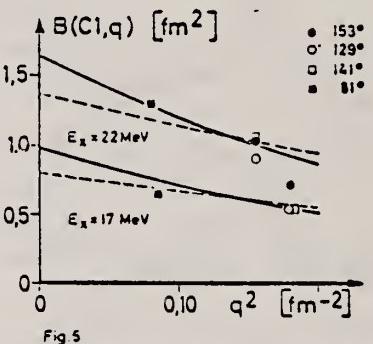


Fig. 4. Reduzierte Matrixelemente für  $^{26}\text{Mg}$ , integriert in den Bereichen 14,5 bis 19,5 MeV („ $E_x = 17 \text{ MeV}''$ ) und 19,5 bis 28,0 MeV („ $E_x = 22 \text{ MeV}''$ ). Die Kurven zeigen die Extrapolation zum Photonenpunkt für  $R_{tr} = 1,3 R_m$  (ausgezogen) bzw.  $R_{tr} = R_m$  (gestrichelt)

METHOD

REF. NO.

70 Kh 1

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	FMF	1	D	225	MAG-D		DST
		(1.81)					

1 = 1.81

Elastic and inelastic scattering of 225-MeV electrons by the isotopes Mg<sup>24</sup> and Mg<sup>26</sup> have been measured. Analysis of the data was carried out in the Born approximation. From analysis of the elastic scattering for a uniform-Gaussian charge-distribution model it is found that addition of two neutrons to the Mg<sup>24</sup> nucleus leads to an increase in the parameter R by  $0.03 \pm 0.02$  fm and a decrease in g by  $0.07 \pm 0.04$  fm, which corresponds to a decrease in the mean-square radius of the Mg<sup>26</sup> nucleus by  $(1.6 \pm 1.3)\%$  in comparison with Mg<sup>24</sup>. Analysis of the inelastic scattering with excitation of the first 2<sup>+</sup> level shows that the internal quadrupole moments of the nuclei Mg<sup>24</sup> and Mg<sup>26</sup> are identical within experimental error.

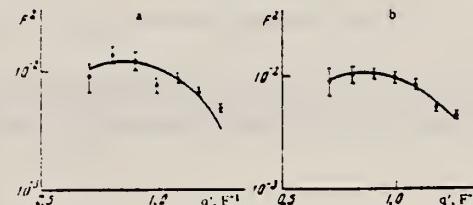


FIG. 3. Form factors for inelastic scattering with excitation of the first 2<sup>+</sup> levels, 1.37 MeV in Mg<sup>24</sup> (a) and 1.81 MeV in Mg<sup>26</sup> (b). The solid lines are theoretical curves calculated with Eq. (3).

#### Characteristics of the first 2<sup>+</sup> levels of the nuclei Mg<sup>24</sup> and Mg<sup>26</sup>

Nucleus	Level energy, MeV	$\beta_1(0^+, 2^+)$	$B(E2\rightarrow)$ , $e^2 F^4$	$\tau, 10^{-13}$ sec	G	$Q_0, F^2$
Mg <sup>24</sup>	1.37	$0.31 \pm 0.02$	$412 \pm 43$	$20.5 \pm 2.4$	$20.1 \pm 2.1$	$64 \pm 4$
Mg <sup>26</sup>	1.81	$0.25 \pm 0.01$	$349 \pm 30$	$6.04 \pm 0.32$	$15.2 \pm 1.3$	$59 \pm 3$

EL EM. SYM.	A	Z
Mg	26	12

METHOD

REF. NO.

70 Ti 1

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E, E/	SPC	12-28	D	50-54	MAG-D		DST
							953

CONST Q = .41 FM-1

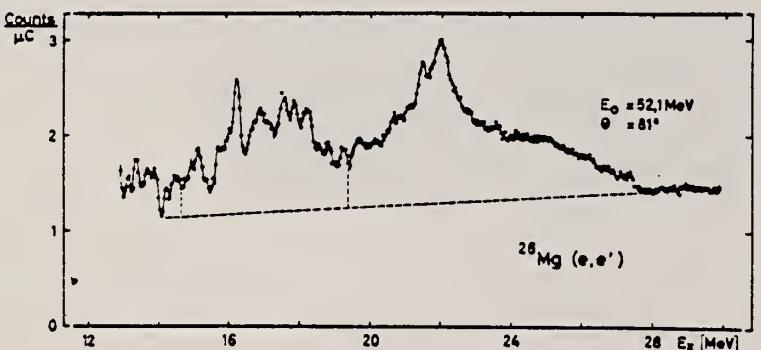


Fig. 1. Spectrum of electrons scattered inelastically from  $^{26}\text{Mg}$  at primary energy 52.1 MeV and scattering angle  $81^\circ$ , after subtraction of the calculated [6] elastic radiation tail;  $E_x$  = excitation energy. The energy resolution at  $E_x = 20$  MeV is about 130 keV. The dashed lines indicate the background subtraction and the separation of the two "bumps".

ELEM. SYM.	A	Z
Mg	26	12

METHOD

REF. NO.

70 Wu 2

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, XN	SPC	11-23	C	19, 23	TOF-D		XX

Data taken but not given at  $E_{\gamma_{max}} = 21.4$  and 27.5 MeV.

XX = NOT GIVEN

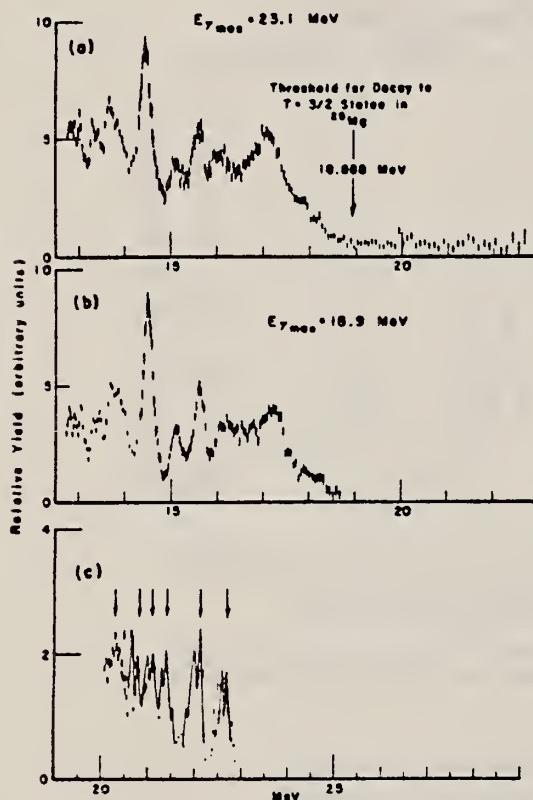


Fig. 2. a) The observed energy spectrum of photoneutrons from the reaction  $^{26}\text{Mg}(\gamma, n)^{25}\text{Mg}$  for a bremsstrahlung end-point energy  $E_{\gamma_{max}} = 23.1$  MeV. The energy scale assumes ground-state transitions. b) The observed energy spectrum of photoneutrons from the reaction  $^{26}\text{Mg}(\gamma, n)^{25}\text{Mg}$  with  $E_{\gamma_{max}} = 18.9$  MeV. The energy scale assumes ground-state transitions. c) The difference spectrum obtained from the two spectra with  $E_{\gamma_{max}} = 23.1$  and 18.9 MeV. The energy scale assumes transitions to the first  $T = \frac{1}{2}$  state in  $^{25}\text{Mg}$  at an energy of 7.7926 MeV (in  $^{25}\text{Mg}$ ). Note the appearance of doublets for the strong transitions: these are attributed to transitions to the 7.7926 and 7.8729 MeV states in  $^{25}\text{Mg}$ . The arrows point to the states seen in the work of ref. [1] and [5].



ELEM. SYM.	A	Z
Mg	26	12

METHOD				REF. NO.	
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	ANGLE
			TYPE	RANGE	
G,N	ABX	11-14 (11.1-13.3)	C	11,14	TOF-D
					DST

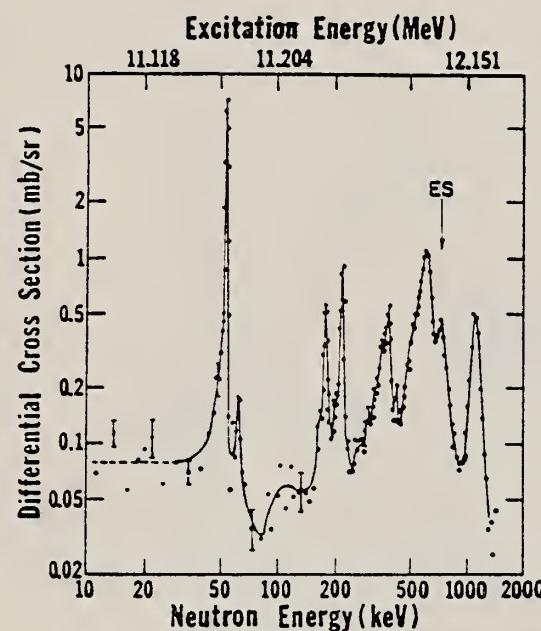


FIG. 17. The 135° differential threshold photo-neutron cross section for  $^{26}\text{Mg}$  (see caption to Fig. 4).

FIG. 4. The 135° differential threshold photoneutron cross section for  $^{207}\text{Pb}$  at low energies versus the energy of the emitted neutron (lower scale) and the excitation energy (upper scale). The arrows indicate peaks which decay to excited states of the residual nucleus (ES), or peaks owing to contaminating isotopes in the photoneutron sample. The inset shows the  $^{207}\text{Pb}(\gamma, n)$  cross section averaged with a square 40-keV wide smoothing function.

Also see:

R. J. Baglan et al.  
Phys. Rev. C3, 2475  
(1971)

[over]

TABLE VII. Resonance parameters for  $^{24,25,26}\text{Mg}$ ,  $^{19}\text{F}$ , and  $^{31}\text{P}$ . For all resonances, the area under the peak in the  $135^\circ$  differential cross section is multiplied by  $4\pi$  to yield approximate values for  $g_\gamma \Gamma_{\gamma_0} \Gamma_n / \Gamma \approx g_\gamma \Gamma_{\gamma_0}$ . For those resonances where  $J^\pi$  is known, the differential area is multiplied by the appropriate factor  $F$  from Table I to obtain  $\Gamma_{\gamma_0}$ .  $E_L$  is the laboratory neutron energy for the  $(\gamma, n)$  reaction and  $E_n$  is the corresponding laboratory neutron energy for a neutron-induced reaction. Column 5 labels the peak as a ground-state (GS) or excited-state (ES) transition as determined in this work alone.

Nucleus	$E_L$ (keV)	$E_{ex}$ (MeV)	$g_\gamma \Gamma_{\gamma_0} \Gamma_n / \Gamma$ (eV)	GS or ES	$J^\pi$	$\Gamma_{\gamma_0}$ (eV)	$E_n$ (keV) (This work)
$^{24}\text{Mg}$	22	16.559	0.61	GS	$(1^-)$	0.40	28
	55	16.596	2.4		$(1^-)$	1.6	66
	110	16.656	4.0		$(1^-)$	2.7	128
	312	16.871	10.7		$(1^-)$	7.1 <sup>a</sup>	354
	382	16.95					432
	717	17.30	19.5		$(1^-)$	13.0 <sup>a</sup>	804
	1210	17.83					1348
	1620	18.26					1799
	1955	18.61					2168
							46.8
$^{25}\text{Mg}$	41.1	7.374	0.09	GS			
	45.1	8.746	0.31				
	74.9	7.410	0.36		$\frac{5}{2}^-$ <sup>b</sup>	1.1	84.1 <sup>b</sup>
	208	8.920	0.29				
	236	7.580	0.09				261
	404	7.756	0.03				445
	439	7.793	0.05		$\frac{1}{2}^+$ <sup>c</sup>		484
	472	7.828	0.06				520
	515	7.873	0.46		$\frac{3}{2}^+$ <sup>c</sup>		567
	601	7.964	0.18				661
	781	8.152	1.51				857
	912	8.292	0.72				1003
	1236	9.999	2.4 <sup>c</sup>		$\frac{3}{2}^+$ or $\frac{5}{2}^+$ <sup>c</sup>		
	1707	9.12					1869
	1764	9.18					1931
$^{26}\text{Mg}$	54.3	11.155	2.6	GS	$1^-(1^+, 2^+)$	1.75	62.3
	63.2	11.164	0.05			0.034	72.2
	181	11.239	1.0		$1^-(1^+, 2^+)$	0.68	202
	222	11.333	1.9		$1^-(1^+, 2^+)$	1.3	248
	391	11.511	5.1		$1^-(1^+, 2^+)$	3.5	433
	621	11.753	32.5		$1^-(1^+, 2^+)$	22.2	684
	738		15.0 <sup>d</sup>			5.1	
	1122	12.279	14.7		$1^-(1^+, 2^+)$	10.0	1232
$^{19}\text{F}$	100	10.542	1.8	GS			118
$^{31}\text{P}$	109	12.429	0.36				121
	230	12.609	0.60				307
	398	12.732	0.59				434
	678	13.026	0.90				737
	939	13.297	4.4				1018

<sup>a</sup>These values for  $\Gamma_{\gamma_0}$ , when increased by approximately a factor of 2 in order to include the relatively high cross sections in the valleys, agree very well with corresponding values from Ref. 3 (see Ref. 4).

<sup>b</sup>This resonance was seen at  $E_n = 83$  and 84 keV in Refs. 24 and 25, respectively.

<sup>c</sup>Analogs of states in  $^{25}\text{Na}$  (see text). The value for  $g_\gamma \Gamma_{\gamma_0} \Gamma_n / \Gamma$  given in Ref. 26 was not corrected with the multiplicative factor in Table II.

<sup>d</sup>Assuming a first-excited-state transition.

<sup>4</sup>R.L. Van Hemert, C.D. Bowman, R.J. Baglan, and B.L. Berman (to be published); R.L. Van Hemert, University of California Lawrence Radiation Laboratory Report No. UCRL-50442, 1968 (unpublished).

<sup>8</sup>S.C. Fultz, M.A. Kelly, J.T. Caldwell, R.R. Harvey, and B.L. Berman, Bull. Am. Phys. Soc. **14**, 103 (1969), and private communication.

<sup>24</sup>H.W. Newson, R.C. Block, P.F. Nichols, A. Taylor, A.K. Furr, and E. Merzbacher, Ann. Phys. (N.Y.) **8**, 211 (1959).

<sup>25</sup>D.J. Hughes and R.B. Schwartz, Neutron Cross Sections (U.S. Government Printing Office, Washington, D.C., 1966), 2nd ed., 2nd Suppl., Vol. IIc.

REF. S.C. Fultz, R.A. Alvarez, B.L. Berman, M.A. Kelly, D.R. Lasher,  
T.W. Phillips, J. McElhinney  
Phys. Rev. C4, 149 (1971)

ELEM. SYM.	A	Z
Mg	26	12

METHOD

REF. NO.

[Page 1 of 3]

71 Fu 2

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,N 344+	ABX	10-29	D	10-29	BF3-I		4PI
G,2N 345	ABX	18-29	D	18-29	BF3-I		4PI

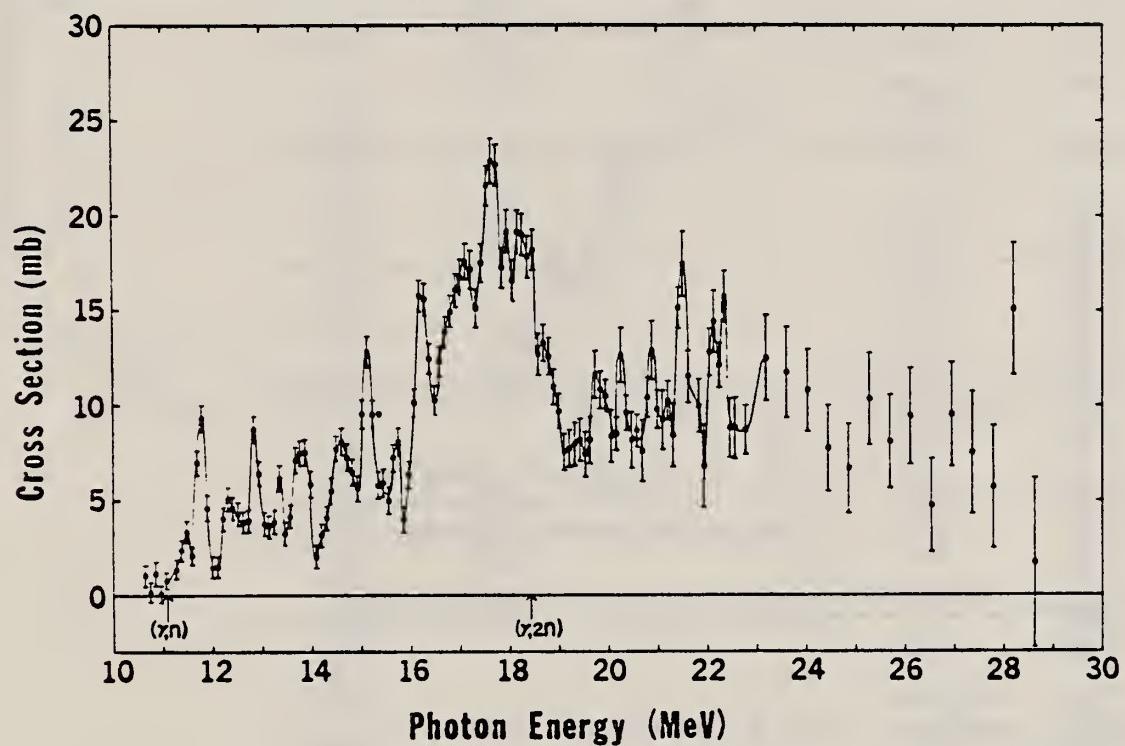


FIG. 4. Single-photoneutron cross section  $\sigma(\gamma, n) + (\gamma, pn)$  for  $^{24}\text{Mg}$ .

TABLE II. Integrated cross sections of magnesium isotopes.

Isotope	$\int_{E_{\text{thr}}}^{28} \sigma(\gamma, n_{\text{tot}}) dE$ (MeV mb)	$\int_{E_{\text{thr}}}^{28} \sigma(\gamma, 2n) dE$ (MeV mb)
$^{24}\text{Mg}$	50	...
$^{26}\text{Mg}$	226	68
Natural magnesium	76	...

[over]

TABLE V. Analytical and experimental resonance energies for  $^{28}\text{Mg}$  (MeV).

Resonance number	Analytical energy	Experimental energies			
		Present data ( $\gamma, \pi_{\text{tot}}$ )	( $\gamma, 2\pi$ )	Livermore (Ref. 15) ( $\gamma, \pi_0$ )	Yale (Ref. 17) ( $\gamma, \pi_0$ )
1	11.17	11.15		11.155 11.164 11.289 11.333	
2	11.46	11.47		11.511	
3	11.75	11.75		11.753	
4	12.35	12.30		12.279	
5	12.80	12.80			12.81 12.90 13.04
6	13.30	13.35			13.35 13.44
7	13.75	13.75 13.83			13.67 13.70 13.89 14.22
8	14.60	14.60			14.49 14.50 14.91
9	15.15	15.15			15.10 15.12
10	15.70	15.70			15.59 15.73
11	16.25	16.20			16.25
12	16.70	16.70			16.90
13	17.05	17.15			17.16
14	17.65	17.65			17.52
15	17.95	17.95			17.83
16	18.20	18.20			18.19
17	18.45	18.45			18.51
18	18.75	18.75	18.80		18.79
19	19.30	19.30	19.32		19.21
20	19.75	19.75	19.63		19.66
21	20.25	20.25	20.05	20.37	20.12
22	20.82	20.87	20.68	20.77	20.59
23	21.20	21.30	21.30	21.16	21.09
24	21.50	21.50		21.37	21.42
25	21.85		21.93		21.93
26	22.15	22.15		22.13	
27	22.30		22.25		22.74
28	23.50	23.00	24.9		23.15 23.60
29	25.35	25.25			
30	26.10				
31	27.00	27.00			27.32
32	28.20	28.20			

<sup>13</sup>O. Titze, A. Goldmann, and E. Spamer,  
Phys. Letters 31B, 565 (1970).

<sup>15</sup>R. J. Baglan, C.D. Bowman, and B.L. Berman,  
Phys. Rev. C3, 672 (1971).

<sup>17</sup>C.-P. Wu, F.W.K. Firk, and B.L. Berman,  
Phys. Letters 32B, 675 (1970).

METHOD

REF. NO.

[Page 3 of 3]

71 Fu 2

hmg

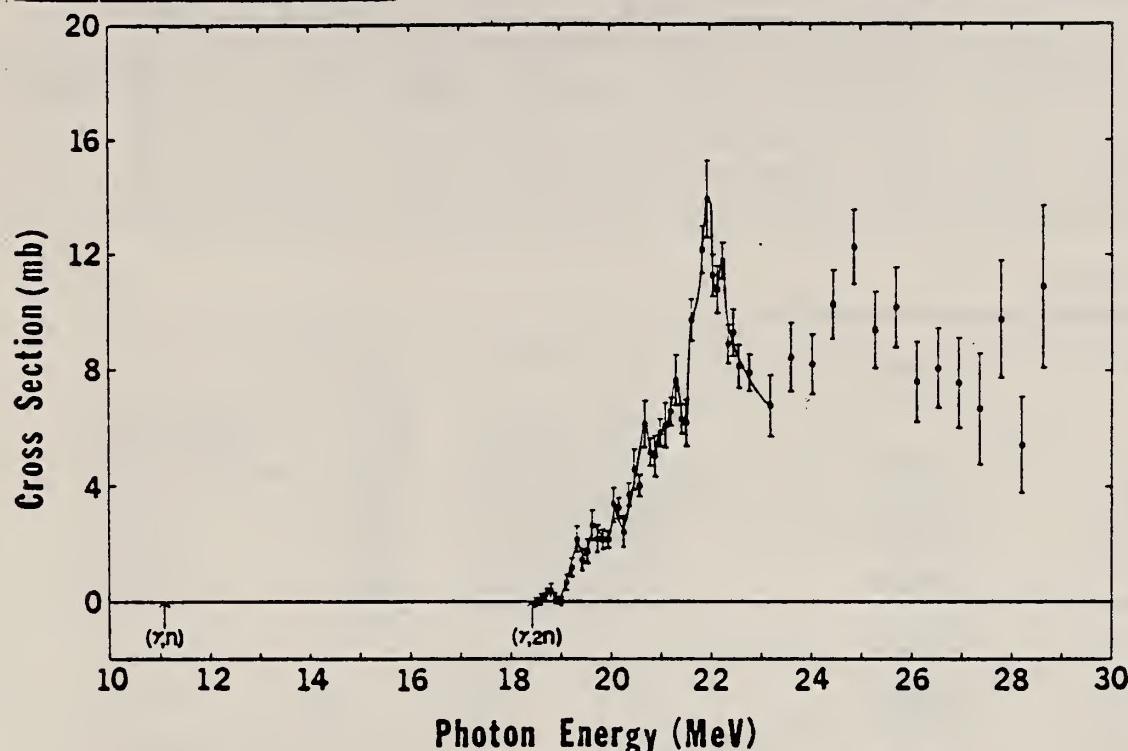


FIG. 5. Double-photoneutron cross section  $\sigma(\gamma, 2n)$  for  $^{26}\text{Mg}$ .

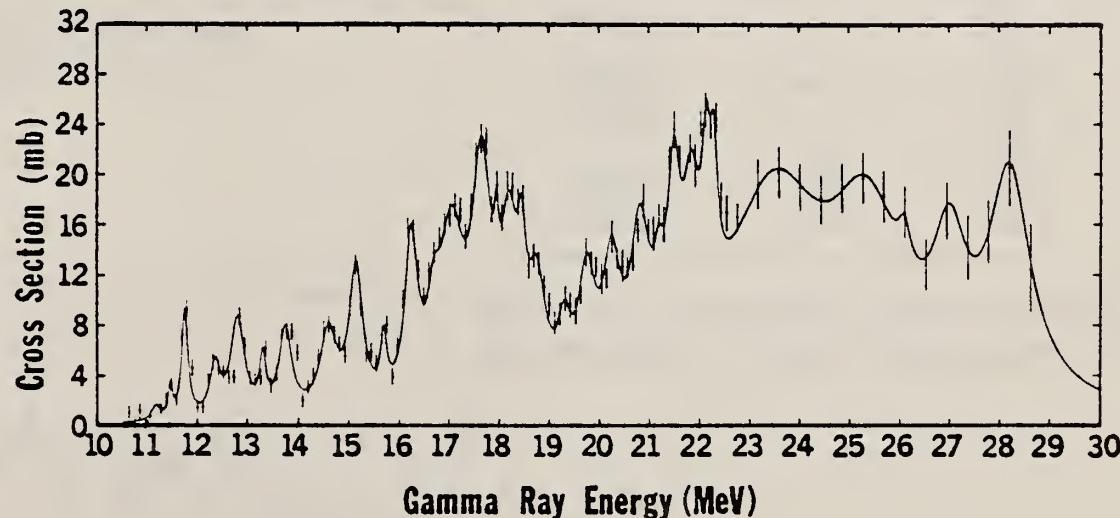


FIG. 7. Total photoneutron cross section  $\sigma(\gamma, n) + \sigma(\gamma, p n) + \sigma(\gamma, 2n)$  for  $^{26}\text{Mg}$ . The solid line is the sum of 32 Lorentz lines with parameters listed in Table VI.

B. S. Ishkhanov, I.M. Kapitonov, E. V. Lazutin, I. M. Piskarev,  
and V. G. Shevchenko  
Nucl. Phys. A186, 438 (1972)

METHOD

REF. NO.

72 Is 1

egf

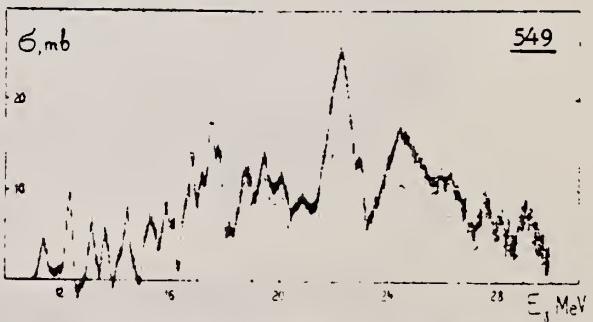
REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,XN	ABX	11-30	C	11-30	BF3-I		4PI

549

TABLE 3

The position of the structural features (MeV) of the giant resonance for  $^{24}\text{Mg}$ 

Ref. <sup>17)</sup>	Ref. <sup>12)</sup>	The present work
11.11		
11.53		$11.40 \pm 0.05$
11.84		
12.37		$12.35 \pm 0.05$
13.1	13.00	$13.15 \pm 0.05$
13.3	13.45	
13.7		$13.60 \pm 0.05$
13.9	13.84	
14.2		
14.5	14.67	$14.45 \pm 0.06$
14.9		
15.1	15.31	$15.25 \pm 0.07$
15.8		$15.85 \pm 0.07$
16.2	16.33	
16.9		$16.80 \pm 0.08$
17.6		$17.50 \pm 0.08$
17.9	17.80	
18.2		
18.8		$18.75 \pm 0.10$
19.2		
19.6		$19.40 \pm 0.10$
20.1	20.20	$20.10 \pm 0.10$
20.7		$20.85 \pm 0.12$
21.1		
21.4		
22.0	22.0	$22.25 \pm 0.15$
23.6	23.6	
24.5	24.8	$24.5 \pm 0.2$

<sup>12</sup>S.C. Fultz et al., Phys. Rev. C4 (1971) 149<sup>17</sup>O. Titze et al., Phys. Lett. 31B (1970) 565

549

Fig. 2. Cross section for  $^{24}\text{Mg}(\gamma, xn)$ . The dashed line shows the expected behaviour of the  $(\gamma, n) + (\gamma, 2n) + (\gamma, np)$  reaction cross section above the  $(\gamma, 2n)$  reaction threshold.

## METHOD

REF. NO.

73 Le 6

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,E/	LFT	2	D	0.4*1.2	MAG-D		UKN

2=1.809 MeV, \* = FM-1

Table 1.

(a) Method	$B(E2, \uparrow)$ ( $e^2 \text{ fm}^4$ )	Reference
Resonance fluorescence	$305 \pm 131$	Rasmussen <i>et al</i> (1961)
Coulomb excitation	$370 \pm 96$	Andreev <i>et al</i> (1961)
Resonance fluorescence†	$570 \pm 231$	Booth <i>et al</i> (1964)
DSA ( $\pi, \pi'\gamma$ )	$370 \pm 37$	Robinson and Bent (1968)
DSA ( $p, p'\gamma$ )	$397 \pm 75$	Hausser <i>et al</i> (1968)
DSA ( $p, p'\gamma$ )	$703 \pm 284$	de Kock <i>et al</i> (1970)
Recoil distance	$305 \pm 131$	McDonald <i>et al</i> (1971)
DSA ( $\pi, p\gamma$ )	$346 \pm 57$ ‡	Durell <i>et al</i> (1972)
(e,e')	$299 \pm 29$ §	Present work

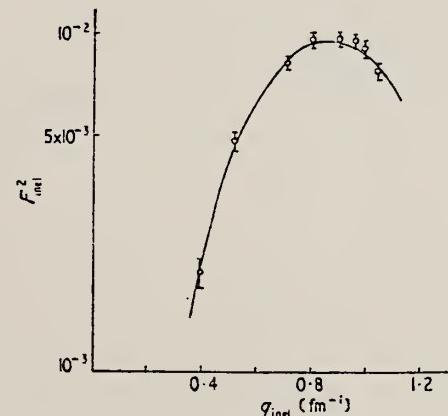
  

(b) Method	$Q_0$ ( $\text{fm}^2$ )	$B(E2, \uparrow)$ ( $e^2 \text{ fm}^4$ )	Reference
( $\pi, \pi'$ ) 104 MeV	(+14 ± 3)	$193 \pm 26$	Rebel <i>et al</i> (1972)
Reorientation	+ 56 ± 14	$311 \pm 156$	Schwalm <i>et al</i> (1972)
	(+42 ± 14)	( $175 \pm 117$ )	

† A natural magnesium target used in this experiment.

‡ ± 25% additional uncertainty in slowing down theory.

§ Corrected for model dependence (see text).

Figure 1. Inelastic form factor for the 1.809 MeV, 2 $^{+}$  level in  $^{26}\text{Mg}$ . The full curve is the best-fit DWBA form factor.

V.V. Varlamov, B.S. Ishkhanov, I.M. Kapitonov, Zh.L. Kocharova,  
 I.M. Piskarev, and O.P. Shevchenko  
 ZhETF Pis. Red. 18, 170 (1973)  
 JETP Letters 18, 99 (1974)

Mg	26	12
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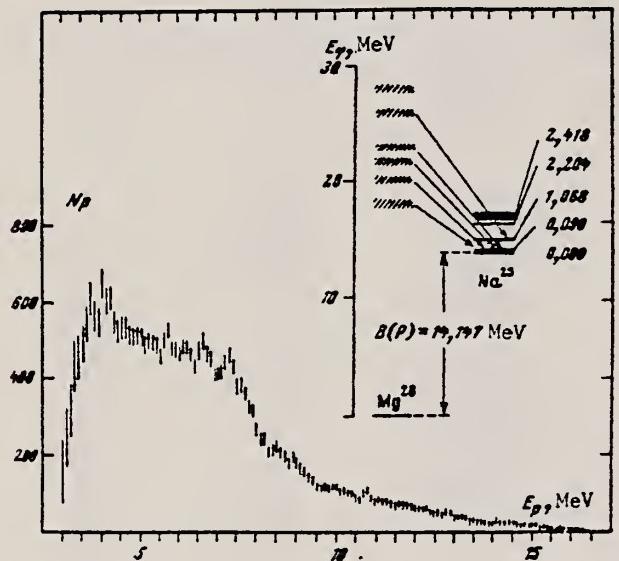
METHOD

REF. NO.

73 Va 7

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,P	SPC	14- 30	C	32	SCD-D		UKN



METHOD

REF. NO.

74 An 1

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G,P	ABX	15-60	C	15- 60	ACT-I		4PI

950

The cross section for the reaction  $^{26}\text{Mg}(\gamma, p)^{25}\text{Na}$  has been measured from 15 to 60 MeV using bremsstrahlung activation methods to obtain the yield curve. The peak cross section of 15.7 mb occurs at 22.6 MeV. Prominent secondary maxima occur at 29.6, 49.0, and 57.9 MeV. The cross section integrated to 28 MeV is  $80 \pm 9$  MeV mb. The cross section integrated to 60 MeV is  $161 \pm 18$  MeV mb. A discussion of our results and comparison with photoneutron data for  $^{26}\text{Mg}$  from other sources is given.

[NUCLEAR REACTIONS  $^{26}\text{Mg}(\gamma, p)$ ,  $E = 15-60$  MeV; measured bremsstrahlung yield; deduced  $\sigma(E)$ .]

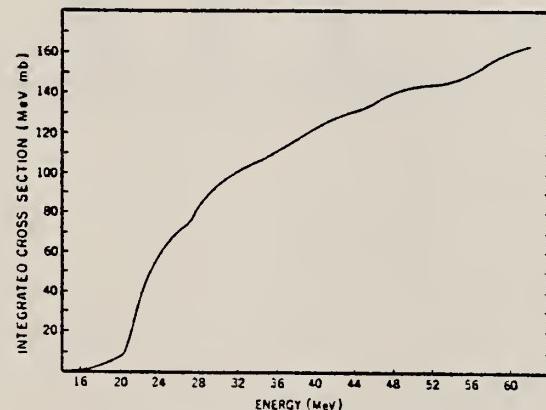


FIG. 5. The integrated cross section for the  $^{26}\text{Mg}(\gamma, p)^{25}\text{Na}$  reaction is displayed as a function of energy.

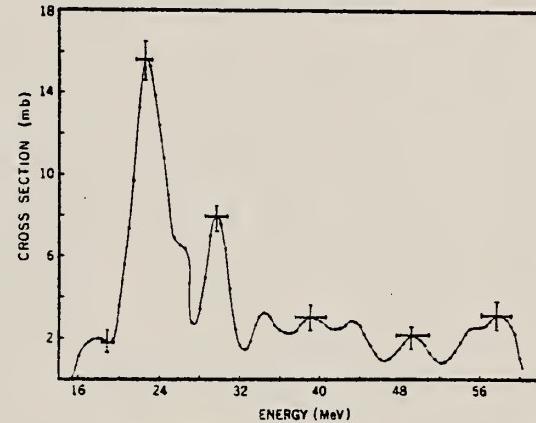


FIG. 3. The cross section for the  $^{26}\text{Mg}(\gamma, p)^{25}\text{Na}$  reaction is shown.



ELEM. SYM.	A	Z
Mg	26	12

METHOD

REF. NO.

74 Le 4

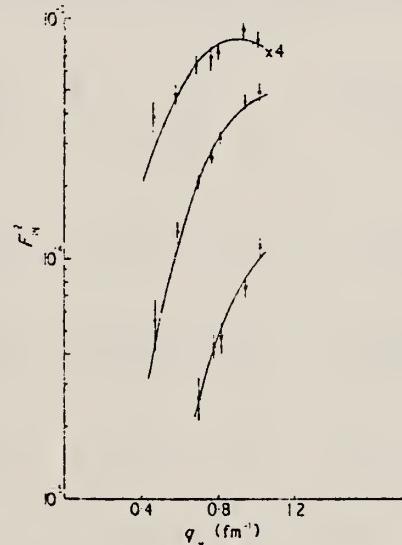
egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
E,E/	LFT	1- 11	D	56-111	MAG-D		DST

 $F^2(q)$  plots given26 LEVELS

Table 2. Electron energies and angles employed in the present experiment.

Run	$E_i$ (MeV)	$\theta$ (deg)	$q_{EL}$ (fm $^{-1}$ )
1	95.74	120	0.84
2	110.71	120	0.97
3	82.75	120	0.73
4	85.09	90	0.61
5	110.45	140	1.05
6	56.89	120	0.50
7	91.28	120	0.80
8	84.16	140	0.80
9	81.36	153	0.80

Figure 7. Inelastic form factors for the 2 $^{+}$  level at 8.892 MeV (○), the 3 $^{-}$  level at 6.876 MeV (●) and the 4 $^{+}$  level at 5.720 MeV (×). The full curves are the corresponding best-fit DWBA form factors.

(over)

Table 7. Results for the analysis of the present data using the basic model and the generalized Helm model

$E_i$ (MeV)	$J^*$	Basic model					Generalized Helm model		
		$t_u$ (fm)	$R_u$ (fm)	$B(U, l)^\dagger$ ( $e^2 \text{ fm}^{2l}$ )	$\beta$	$\gamma^0$	$R$ (fm)	$R_u$ (fm)	$B(U, l)^\dagger$ ( $e^2 \text{ fm}^{2l}$ )
1.899	2*	2.76	2.16	$4.13 \pm 0.12$	$2.75 \pm 2.0$	1.937	$2.90 \pm 0.09$	$4.04 \pm 0.06$	$2.66 \pm 1.6$
2.945	2*	1.92	2.61	4.27	7.4	0.346	$2.71 \pm 0.34$	$3.90 \pm 0.33$	$6.5 \pm 1.4$
3.579	0*	2*	2.47	2.26	4.08	$2.7 \times 10^{-2}$	$4.46 \times 10^{-2}$	$5.18 \pm 0.35$	$6.17 \pm 0.30$
4.337	2*	1.83	2.31†	5.59	$3.4 \times 10^4$	1.11	$2.75 \pm 0.56$	$1.93 \pm 0.39$	$2.6 \pm 1.0$
4.875	4*	1.83	2.31†	5.59	$3.4 \times 10^4$	1.11	$3.47 \pm 0.60$	$4.94 \pm 0.42$	$(2.6 \pm 0.7) \times 10^4$
4.979	0*	0	2*	1.82	2.20	3.68	$3.31 \times 10^{-2}$	$5.32 \pm 0.31$	$6.39 \pm 0.27$
5.294	2*	2*	2.39†	5.94†	$4.6 \times 10^3$	0.248	$0.156 \pm 0.110$	$2.13 \pm 0.38$	$3.32 \pm 0.23$
5.449	4*	2*	2.39†	5.94	$1.7 \times 10^4$	0.480	$3.91 \pm 0.66$	$5.26 \pm 0.49$	$3.4 \times 10^3$
5.720	4*	2.75	2.39	5.94	$2.14 \times 10^{-2}$	5.251	$6.21†$	$4.4 \pm 1.1$	$(1.3 \pm 0.5) \times 10^4$
6.216	0*	2.27	2.47	5.07	750	0.677	$3.34 \pm 0.33$	$4.62 \pm 0.24$	$6.38 \pm 10.1$
6.876	3-	2.27	2.47	5.07	750	0.677	$0.177 \pm 0.142$	$2.79 \pm 0.30$	$3.5 \pm 0.6$
7.082	2*	2*	2.47†	5.07†	531	0.704	$0.409 \pm 0.081$	$2.12 \pm 0.15$	$3.52 \pm 0.09$
7.364	2*	2.27†	2.47†	5.07†	531	0.577	$3.32 \pm 0.69$	$4.0 \pm 0.30$	$10.0 \pm 0.6$
7.691	3-	2.27†	2.47†	5.11	1050	0.643	$0.617 \pm 0.200$	$3.06 \pm 0.23$	$4.46 \pm 2.3$
7.830	3-	3.06	2.31†	5.11	1050	0.195	$0.508 \pm 0.068$	$2.13†$	$3.06 \pm 0.16$
8.181	3-	2.31†	5.11	1050	0.643	0.813	$3.63 \pm 0.26$	$4.83 \pm 0.20$	$9.47 \pm 1.54$
8.526	2*	1.86	2.63	4.27	5.4	0.293	$2.74 \pm 0.35$	$3.93 \pm 0.24$	$4.8 \pm 1.0$
8.892	2*	1.86	2.63	4.27	5.4	0.159	$2.79 \pm 0.63$	$3.96 \pm 0.44$	$1.5 \pm 0.5$
9.287	2*	2.45	2.31†	4.13	1.6	0.82	$0.293 \pm 0.135$	$3.40 \pm 1.59$	$1.5 \pm 0.9$
9.560	2*	1.85	2.40	3.29	$1.14 \times 10^{-2}$	$0.619 \pm 0.168$ ‡	$0.623 \pm 0.198$ ‡	$3.32 \pm 0.20$	$(1.3 \pm 0.9) \times 10^{-2}$
10.199	1*	2.39†	2.39†	3.29	$1.14 \times 10^{-2}$	0.350	$0.264 \pm 0.115$	$3.53 \pm 0.88$	$4.76 \pm 0.65$
10.330	3-	2*	2.31†	4.09	4.5	0.304	$0.238 \pm 0.120$	$1.98 \pm 0.92$	$2.38 \pm 1.15$
10.491	2*	3.65†	2.40†	3.29†	$1.3 \times 10^{-2}$	0.632§	$0.669$	$3.44 \pm 0.32$	$1.4 \pm 0.6$
10.65	1*	2.39†	2.39†	5.94†	$9.7 \times 10^3$	0.168	$3.91†$	$5.26 \pm 0.92$	$1.5 \times 10^{-2}$
10.680	4*	2.38	2.31†	4.09	4.5	0.278	$2.72 \pm 0.62$	$3.91 \pm 0.42$	$4.3 \pm 1.2$
10.838	2*	2.13	2.31†	3.97	3.7	0.295	$2.51 \pm 0.50$	$3.76 \pm 0.33$	$3.4 \pm 0.8$

†  $B(U, l)$  ( $l = E$  or  $M$ ) is the ground state reduced transition probability for excitation to the level of spin  $L$ .

‡ Denotes that the radius parameter for this level was fixed.

§ The value of the square of the matrix element is quoted for this level in  $e^2 \text{ fm}^4$ .

||  $R_u$  not evaluated since this level has a strong transverse component.

¶ Values for  $\gamma^+$  and  $\gamma^-$  for magnetic states are given under the columns  $\beta$  and  $\gamma^0$  respectively.

REF.

V.V. Varlamov, B.S. Ishkhanov, I.M. Kapitonov, I.M. Piskarev,  
 V.G. Shevchenko, and O.P. Shevchenko  
 Nucl. Phys. A222, 548 (1974)

ELEM. SYM.

Mg	26	12
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METHOD

REF. NO.

74 Va 2

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, xp	ABX	15- 29	C	8- 29	ION-I		4PI

$$^{29}_{15} \sigma_{xp} = 140 \pm 20 \text{ MeV-mb}$$

951

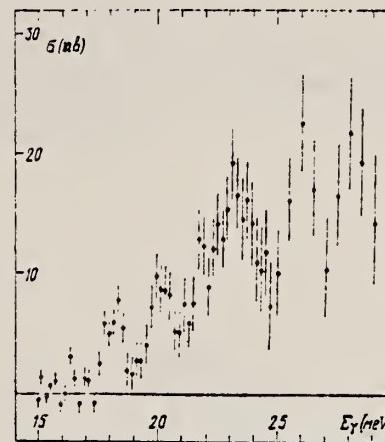


Fig. 2. The  $^{26}\text{Mg}(\gamma, \text{xp})$  reaction effective cross section.



ELEM. SYM.	A	z
Mg	26	12
REF. NO.	74 Wo 5	egf

METHOD				REF. NO.	egf	
REACTION	RESULT	EXCITATION ENERGY	SOURCE			
Type	Range	Type	Range	ANGLE		
G.P	ABY	16- 23	C	24, 31	TEL-D	DST
G.A	ABY	16- 23	C	24, 31	SCD-D	90

Assumes all ground-state transitions to obtain a cross section. The total ground-state cross sections used to obtain the integrals given in Table 2 were obtained by assuming that the angular distribution measured for presumed ground-state protons produced by 22.1 MeV photons held for all photon energies below 23 MeV.

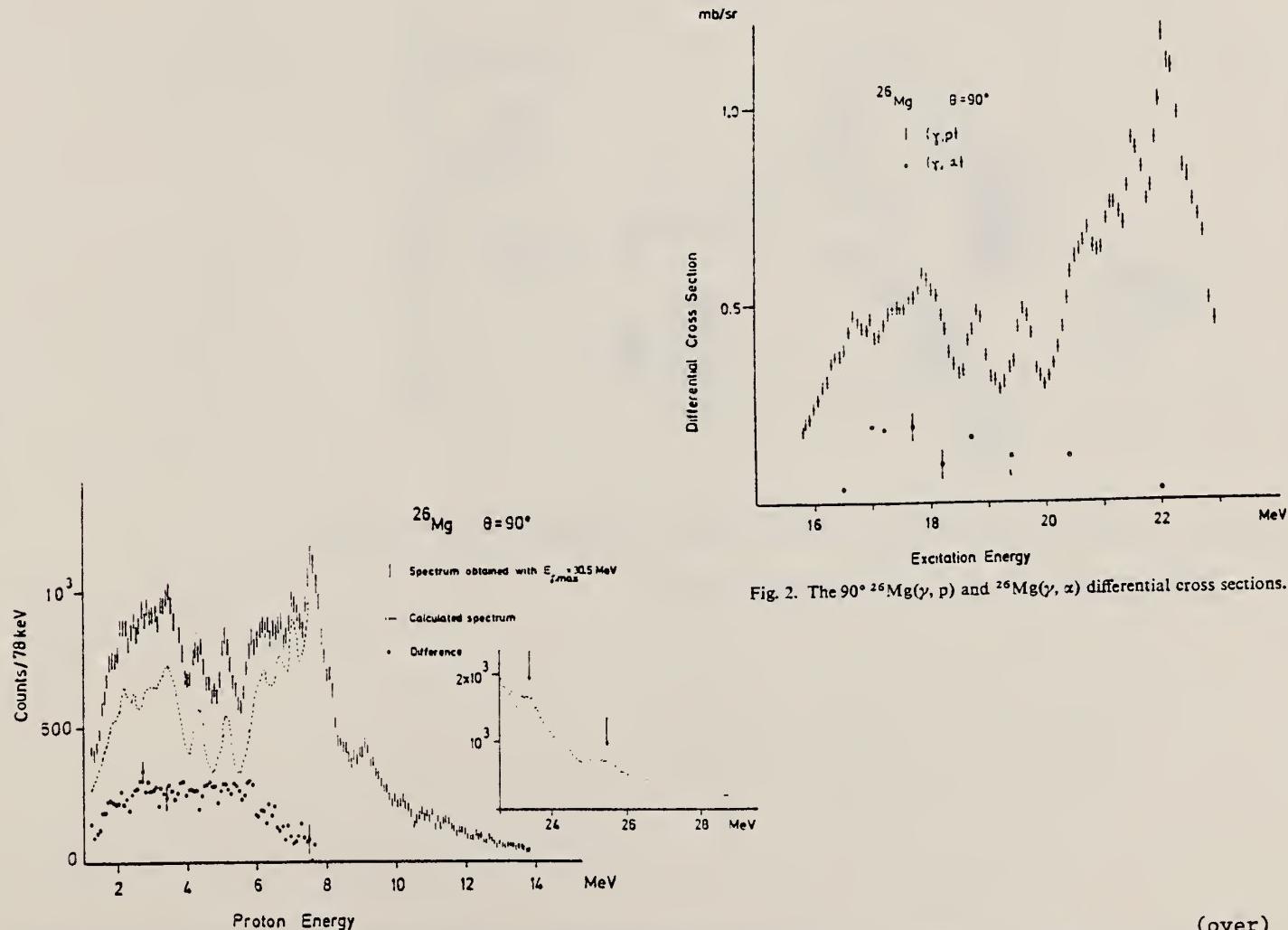


Fig. 2. The  $90^\circ$   $^{26}\text{Mg}(\gamma, p)$  and  $^{26}\text{Mg}(\gamma, \alpha)$  differential cross sections.

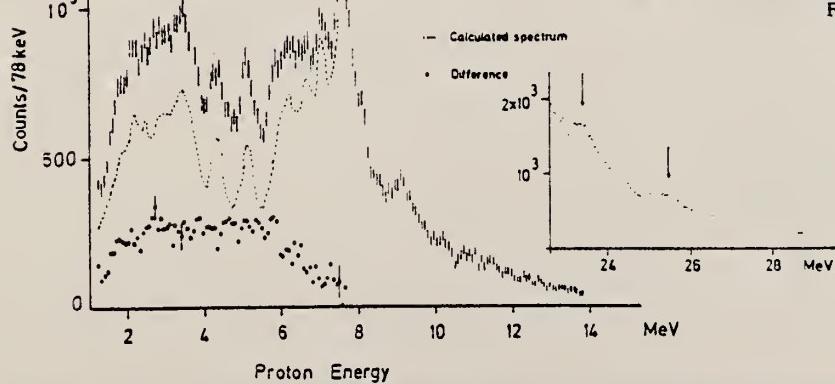


Fig. 3. The  $^{26}\text{Mg}(\gamma, p)$  proton spectrum obtained at 30.5 MeV bremsstrahlung endpoint energy, showing a large excess of low-energy protons.

(over)

TABLE 2  
Integrated and "bremsstrahlung-weighted" integrated proton and neutron cross sections

Excitation energy region of integration (MeV)	$\int \sigma(E)dE$ (MeV · mb)			$\int (\sigma(E)/E)dE$ (mb)		
	( $\gamma$ , p)	( $\gamma$ , n <sub>tot</sub> )	( $\gamma$ , p) + ( $\gamma$ , n <sub>tot</sub> )	( $\gamma$ , p)	( $\gamma$ , n <sub>tot</sub> )	( $\gamma$ , p) + ( $\gamma$ , n <sub>tot</sub> )
16.0-18.5	9.4	41.67	51.1	0.56	2.4	2.96
16.0-20.0	14.3	59.16	73.44	0.81	3.31	4.12
16.0-23.0	32.8	112.4	142.5	1.66	5.86	7.52

ELEM. SYM.	A	Z
Mg	26	12

METHOD	REF. NO.	
	74 Wo 7	egf
REACTION	RESULT	EXCITATION ENERGY
G, NG	ABI	19- 23
		C 30
		SCD-D
		90

The population of  $T = 3/2$  states in  $^{25}\text{Mg}$  from the giant dipole resonance in  $^{26}\text{Mg}$  was observed by the  $^{26}\text{Mg} (\gamma, \gamma')$  reaction. The previously reported result, that neutron decay between 18.9 MeV and 23.0 MeV proceeds mainly to these states, could not be confirmed. Therefore the isospin splitting of the giant resonance of  $^{26}\text{Mg}$  remains questionable.

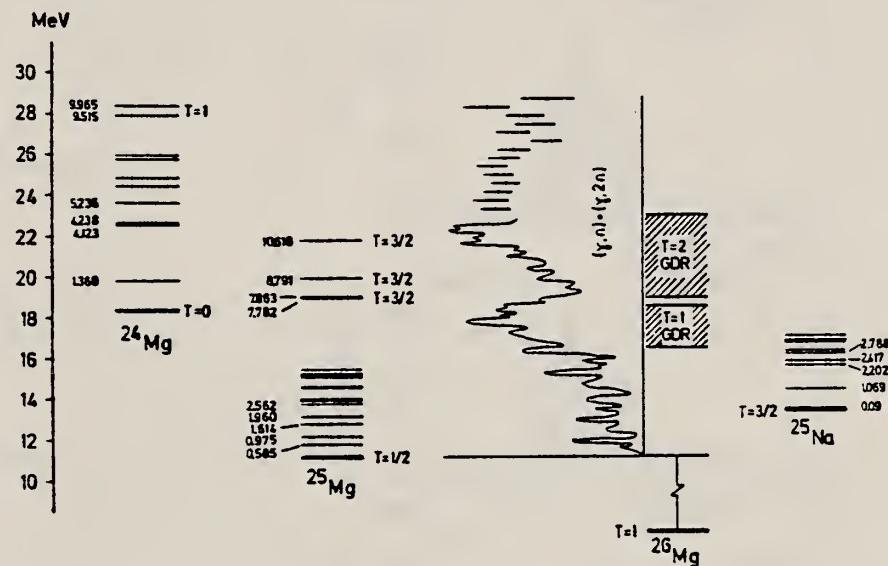


Fig. 1. Energy levels of residual nuclei from the  $^{26}\text{Mg} (\gamma, x\gamma)$  reaction. The  $(\gamma, n) + (\gamma, 2n)$  curve and data points are from ref. [5].

S.C. Fultz et al., Phys. Rev. C4 (1971) 149.



METHOD

REF. NO.

75 Ku 4

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
A, G	ABX	14- 24	D	5- 16	NAI-D		DST

$E_x$  in  $^{26}\text{Mg}$  (MeV)

SEE ANALYSIS 79KU5

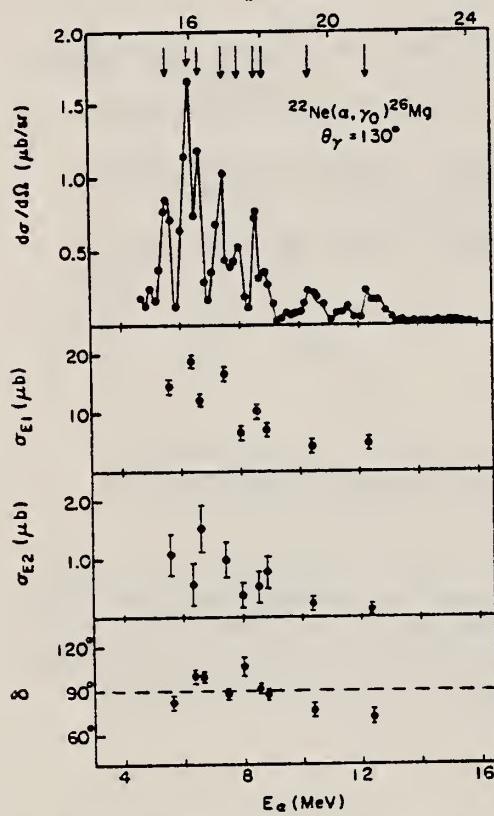


FIG. 6. Top: excitation function for the reaction  $^{22}\text{Ne}(\alpha, \gamma)$  at  $\theta = 130^\circ$ . Middle: the extracted  $E1$  and  $E2$  total cross sections for the  $(\alpha, \gamma)$  reaction. Bottom: the  $E2$  phase relative to the  $E1$  phase.

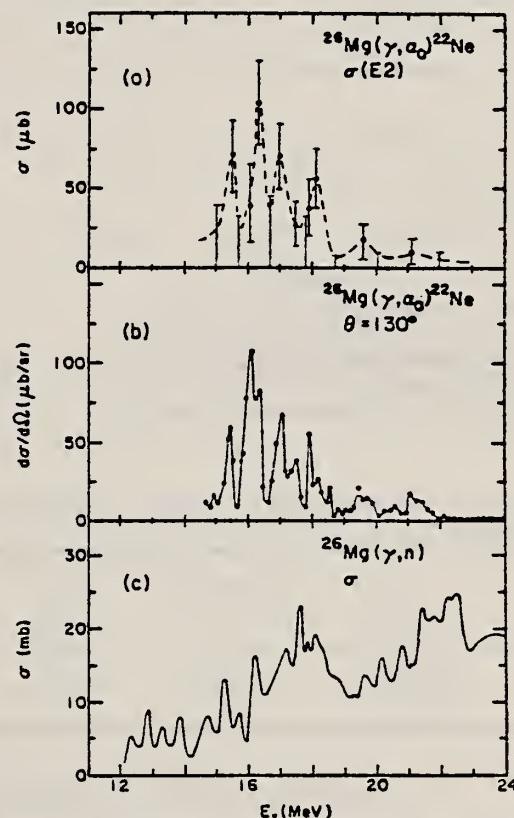


FIG. 7. (a) the extracted  $E2$  cross section converted by detailed balance to the total  $E2$  cross section for the reaction  $^{26}\text{Mg}(\gamma, \alpha)^{22}\text{Ne}$ . (b) the excitation function ( $E1 + E2$ ) at  $\theta = 130^\circ$  for the reaction  $^{26}\text{Mg}(\gamma, \alpha)^{22}\text{Ne}$ . (c) the cross section for  $^{26}\text{Mg}(\gamma, n)$  obtained with mono-energetic photons (Ref. 15).

(over)

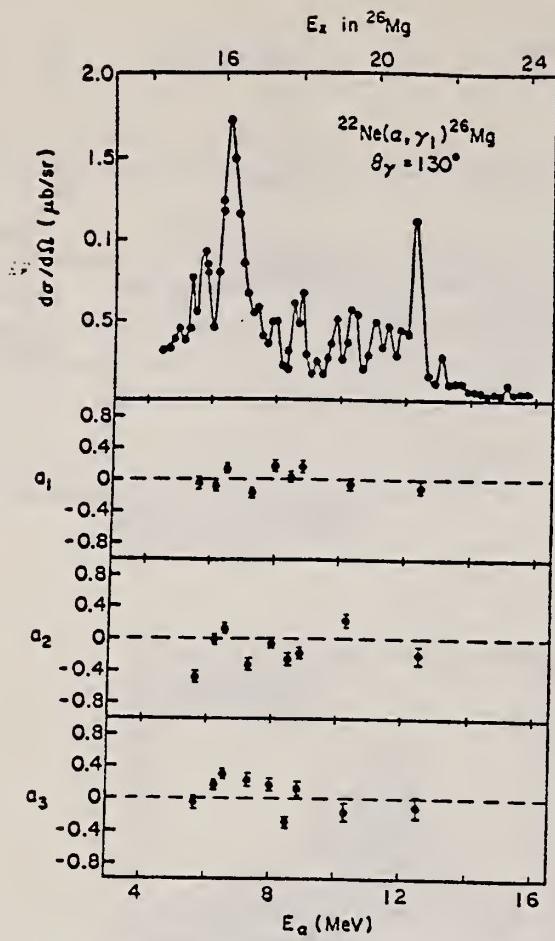


FIG. 8. The excitation function at  $\theta = 130^\circ$  and the coefficients  $a_1$ ,  $a_2$ , and  $a_3$  from a Legendre polynomial fit to the angular distributions for the reaction  $^{22}\text{Ne}(\alpha, \gamma_1)^{26}\text{Mg}$  (1.81 MeV). In this case the  $a_2$  fluctuates about a value of -0.12 in contrast to the behavior for  $^{20}\text{Ne}(\alpha, \gamma_1)$ .

TABLE II. Summary of  $E2$  strengths in  $^{24,26}\text{Mg}(\gamma, \alpha_0)$  (see text) given in percent of the  $E2$  sum rule [Eq. (5)].

Nucleus	$\Delta E$ (MeV)	$\int \sigma(E2)/E^2 dE$ (%)	$\Delta E$ (MeV)	$\int \sigma_{\text{tot}}^{\text{CN}}(E2)/E^2 dE$ (%)
$^{24}\text{Mg}$	12.0–22.5	$11.8 \pm 1.0$	0–22.5	$120 \pm 30$
$^{26}\text{Mg}$	15.0–21.4	$6.0 \pm 2.0$	0–21.4	$290 \pm 80$

TABLE III. A comparison of the integrated  $E1$  strengths found in various reactions in the GDR's of  $^{24}\text{Mg}$  and  $^{26}\text{Mg}$ . The strengths are given in percent of the  $E1$  sum rule [Eq. (4)].

Nucleus	$(\gamma, \alpha)$			$(\gamma, p_0)$ <sup>a</sup>			$(\gamma, n)$ <sup>b</sup>			$(e, e')$ <sup>c</sup>		
	$\Delta E$ (MeV)	$\int \sigma(E1)dE$ (%)	$\Delta E$ (MeV)	$\int \sigma(E1)dE$ (%)	$\Delta E$ (MeV)	$\int \sigma(E1)dE$ (%)	$\Delta E$ (MeV)	$\int \sigma(E1)dE$ (%)	$\Delta E$ (MeV)	$\int \sigma(E1)dE$ (%)	$\Delta E$ (MeV)	$\int \sigma(E1)dE$ (%)
$^{24}\text{Mg}$	14.6–20.6	0.33	15.5–23.0	3.3	16.5–28.0	14.0	16.0–22.0	30.0				
$^{26}\text{Mg}$	14.8–21.0	0.70	...	...	11.0–28.0	58.0	14.5–28.0	48.0				

<sup>a</sup> Reference 14.

<sup>b</sup> Reference 15.

<sup>c</sup> References 19 and 27.

REF.

V.V. Varlamov, F.A. Zhivopistsev, B.S. Ishkhanov, A.V. Lukashev  
 Izv. Akad. Nauk SSSR. Ser. Fiz. 39, 131 (1975)  
 Bull. Acad. Sci. USSR Phys. Ser. 39, 113 (1975)

ELEM. SYM.	A	Z
Mg	26	12

METHOD

REF. NO.

75 Va 3

hmg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, P	SPC	17 - 32	C	32	SCD-D		UKN

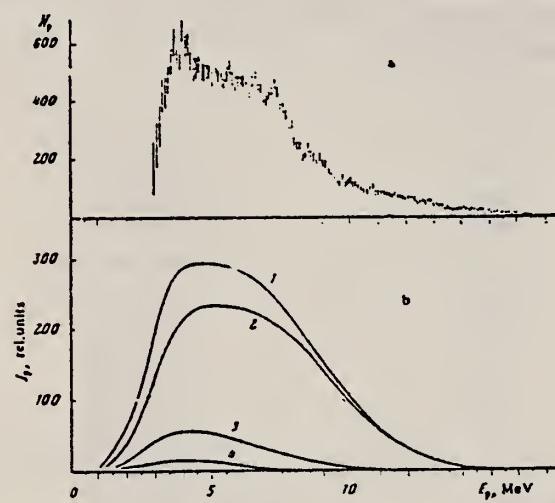


Fig. 1. Comparison of the results of the calculation with experimental data: a) experimental photoproton spectrum; b) calculated spectra of the protons escaping at various stages of the process involving linkages with more complex states: 1) (2p-2h) + (3p-3h) + (4p-4h); 2) (2p-2h); 3) (3p-3h); 4) (4p-4h).

REF.	V.V. Varlamov, B.S. Ishkhanov, I.M. Kapitonov, Zh.L. Kocharova, V.I. Shvedunov, and O.P. Shevchenko Izv. Akad. Nauk SSSR, Ser. Fiz. 39, 1744 (1975) Bull. Acad. Sci. USSR Phys. Ser. 39, 150 (1975)	ELEM. SYM.	A	Z	
METHOD		Mg	26	12	
REF. NO.			75 Va 4	hmg	
REACTION	RESULT	EXCITATION ENERGY	SOURCE	DETECTOR	
G, P	SPC	14- 32	C 19- 32	SCD-I	ANGLE
					90

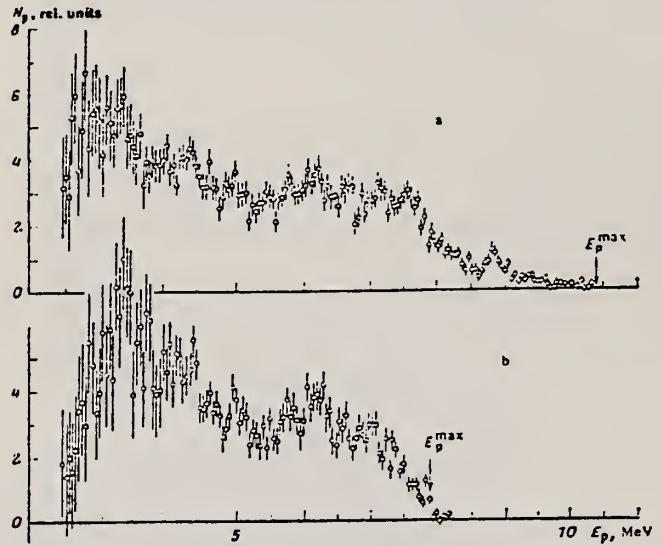


Fig. 1. Spectra of photoprottons from  $^{26}\text{Mg}$  obtained for two values of  $E_{\gamma}^{\text{max}}$ : 24.5 MeV (a) and 22.0 MeV (b).

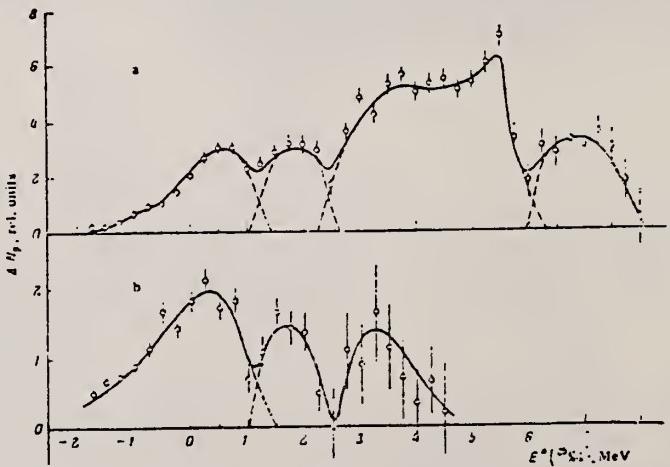


Fig. 2. Resultant distribution of  $\Delta N_p(E_{\text{f.n.}})$  obtained for different excitation-energy bands of  $^{26}\text{Mg}$ : a) 22.0-27.0 MeV; b) 19.5-22.0 MeV.

METHOD

REF. NO.

76 Ba 2

egf

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, PG	ABY	15- 30	C	24, 30	SCD-D		90
G, NG	ABY	12- 30	C	24, 30	SCD-D		90

TABLE 5

Results of the  $^{26}\text{Mg}(\gamma, x\gamma')$  experiment, giving "bremsstrahlung-weighted" integrated cross sections in MeV · mb for the population of excited residual nuclear states

Bremsstrahlung endpoint energy (MeV)			
	23.5	30.0	
(a) $^{25}\text{Na}$ states			
g.s. $\frac{1}{2}^+$			
90 keV, $(\frac{1}{2}, \frac{3}{2})^+$	$10.10^a)$	?	
1069 keV, $\frac{1}{2}^+$	$<1.9$	$<2.7$	
2914 keV, $(\frac{1}{2}, \frac{3}{2})^+$	0.8	1.0	
(b) $^{25}\text{Mg}$ states			
g.s. $\frac{1}{2}^+$	$35.93^b)$	?	
585 keV, $\frac{1}{2}^+$	$<3.6$	$<3.5$	
974 keV, $\frac{3}{2}^+$	4.0	3.2 (?)	
1611 keV, $\frac{7}{2}^+$	1.9	2.7	
1965 keV, $\frac{5}{2}^+$	1.1	2.1	
2564 keV, $\frac{1}{2}^+$	3.2	4.1	
2801 keV, $\frac{3}{2}^+$	2.0	2.8	
3901 keV, $(\frac{1}{2}, \frac{3}{2})^+$	0.8	1.8	
4354 keV, $\frac{5}{2}^+$	1.7	1.63 (?)	
4715 keV, ?	1.2	1.08 (?)	
7784 keV, $(\frac{1}{2}, \frac{3}{2})^+ T = \frac{1}{2}$	2.57	3.1	
7864 keV, $(\frac{1}{2}, \frac{3}{2})^+ T = \frac{1}{2}$	0.3	0.35	
(c) $^{24}\text{Mg}$ states			
1369 keV, $2^+$	0.8	2.6	
(d) $^{22}\text{Ne}$ states			
1275 keV, $2^+$	1.6	2.03	
Sum of observed $(\gamma, p)$ excited state cross section	2.7	3.7	
Sum of observed $(\gamma, n)$ excited state cross section	22.37	26.35	
Proton yield <sup>a</sup> )	12.8		
$(\gamma, n) + (\gamma, np)$ yield <sup>b</sup> )	58.31	80.2	
$(\gamma, 2n)$ yield <sup>b</sup> )	7.2	25.22	

Bremsstrahlung spectra normalized at 10.6 MeV.

<sup>a</sup>) Calculated from the data of ref. <sup>4</sup>).

<sup>b</sup>) Calculated from the data of ref. <sup>2</sup>).

<sup>2</sup>S.C. Fultz et al., Phys. Rev. C4, 149 (1971); R.A. Alvarez et al., Phys. Rev. C4, 1673 (1971).

<sup>4</sup>H. Wolf et al., Nucl. Phys. A234, 365 (1974).

ELEM. SYM.	A	Z
Mg	26	12
REF. NO.		
77 Wi 1	egf	

METHOD

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR	
			TYPE	RANGE	TYPE	RANGE
G,P	ABX	16-24	O	24	TEL-D	DST
				(23.5)		

Assumes all ground state transitions

TABLE I  
Integrated and "bremsstrahlung-weighted" integrated proton cross sections

Excitation energy region of integration (MeV)	$\int \sigma(\gamma, p)dE$ (MeV · mb)	$\int (\sigma(\gamma, p)/E)dE$ (mb)
16.0-18.5	14.8	0.88
16.0-20.0	22.1	1.26
16.0-23.0	52.0	2.64

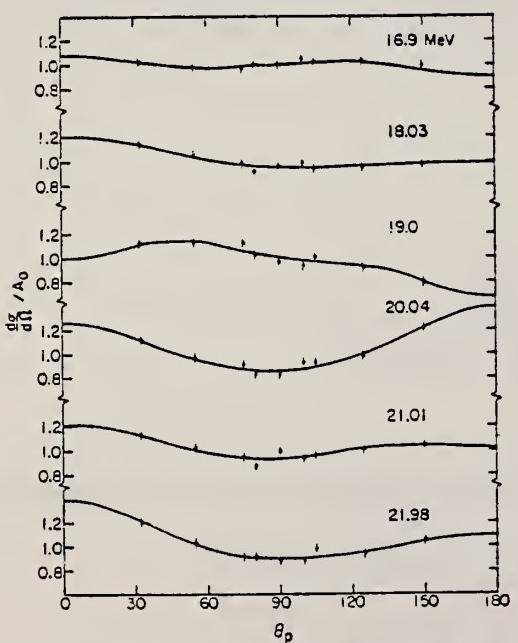


Fig. 1. Some angular distributions of the  $^{26}\text{Mg}(\gamma, p)$  reaction. The solid lines through the data points are Legendre polynomial fits as discussed in the text. The error bars represent statistical uncertainties only.

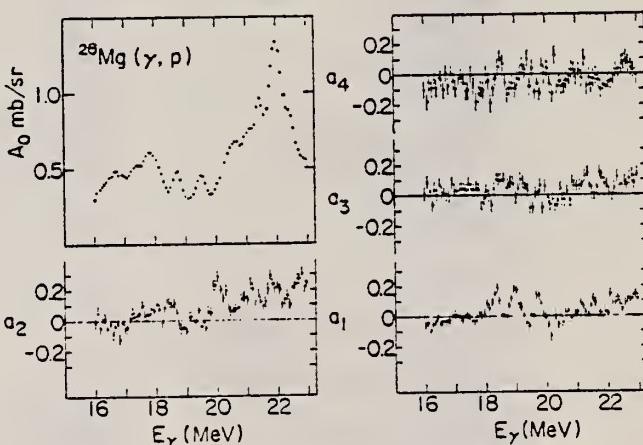


Fig. 2. Angular distribution coefficients.

METHOD

REF. NO.

79 Is 2

hg

REACTION	RESULT	EXCITATION ENERGY	SOURCE		DETECTOR		ANGLE
			TYPE	RANGE	TYPE	RANGE	
G, PJ	ABX	14-27	C	19-27	MAG-D		UKN

**Abstract:** The energy spectra of photoprottons from  $^{26}\text{Mg}$  have been measured with bremsstrahlung at five values of the end-point energy  $E^{\text{max}}$ , namely, at 19.5, 20.5, 22.0, 24.5 and 27.0 MeV. Using the difference spectra technique, we have determined the main decay channels of the states of the giant dipole resonance (GDR) of  $^{26}\text{Mg}$ . The photoprotton spectra have been used to obtain the cross sections for the formation of the final nucleus of the  $^{26}\text{Mg}(\gamma, p)^{23}\text{Na}$  reaction in its various states. The magnitude of the configurational splitting of the GDR of  $^{26}\text{Mg}$  has been estimated. Relevant data from other studies have been utilized to calculate the isospin components of the GDR of  $^{26}\text{Mg}$  within the framework of a combined model for the decay of the giant resonance, with isospin taken into account. A new isospin interpretation of the cross sections for the photoprotton and photoneutron reactions on the  $^{26}\text{Mg}$  nucleus is proposed.

 $J=0+1, 3, 6$ 

E NUCLEAR REACTION  $^{26}\text{Mg}(\gamma, p)$ .  $E = 19.5, 20.5, 22.0, 24.5, 27.0$  MeV; measured photoprotton energy spectra; deduced  $\sigma$  for different final states. Configurational and isospin splitting of GDR discussed. Enriched target.

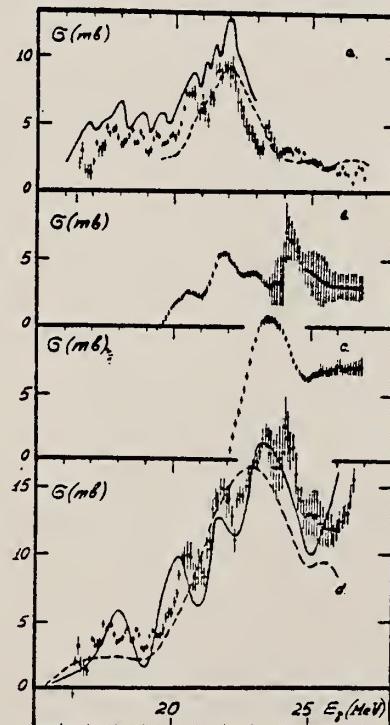


Fig. 4. Results of the calculation of the partial cross sections for the photoprotton reaction on  $^{26}\text{Mg}$ . (a) The cross section  $\sigma_{\pi_0 + \pi_0}$ ; solid curve: data of ref. <sup>8</sup>), dotted curve: data of ref. <sup>9</sup>). (b) The cross section  $\sigma_{\pi_0 + \pi_1}$ . (c) The cross sections  $\sigma_{\pi_1 + \pi_1}$ . (d) The sum of the cross sections  $\sigma_{\pi_0 + \pi_0} + \sigma_{\pi_1 + \pi_1} + \sigma_{\pi_0 + \pi_1}$ ; solid curve: data of ref. <sup>4</sup>); dotted curve: data of ref. <sup>5</sup>).

TABLE I  
 Integrated cross sections for the partial photoprotton reactions on  $^{26}\text{Mg}$

Reaction	$\Delta E$ (MeV)	$\int_{E_{\text{th}}}^{19.5} \sigma dE$	$\int_{E_{\text{th}}}^{24.5} \sigma dE$	$\int_{E_{\text{th}}}^{27.0} \sigma dE$
( $\gamma, p_0 + p_1$ )	0.3	$19.8 \pm 1.2$	$37.9 \pm 2.4$	$41.2 \pm 2.6$
( $\gamma, p_0 + p_1$ )	0.8	$2.9 \pm 0.2$	$18.1 \pm 1.6$	$26.8 \pm 3.1$
( $\gamma, p_{-0}$ )	1.0	$20.9 \pm 3.0$	$15.9 \pm 1.2$	$39.2 \pm 1.4$
( $\gamma, p$ )			$66.3 \pm 9.5$	$101.3 \pm 14.4$

(over)

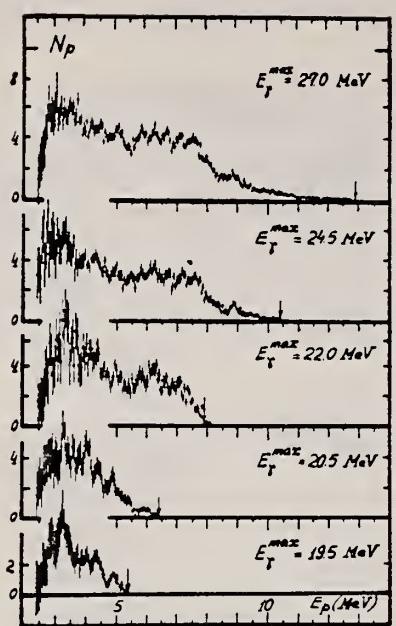


Fig. 1. Spectra of photoprotons (arb. units) from  $^{26}\text{Mg}$  obtained for the various endpoint energies of the bremsstrahlung  $\gamma$ -radiation  $E_T^{\text{max}}$ .

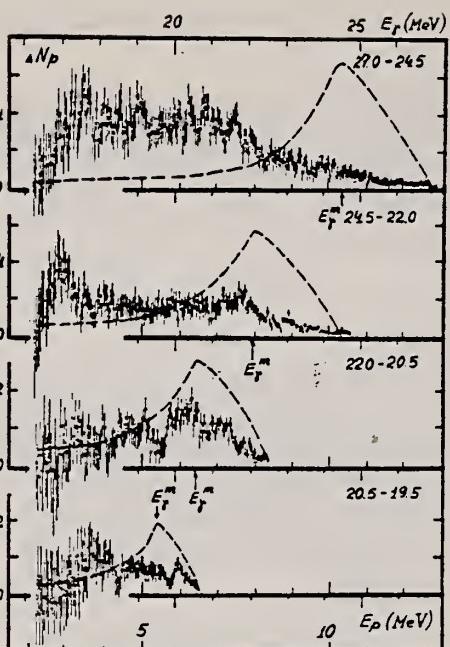
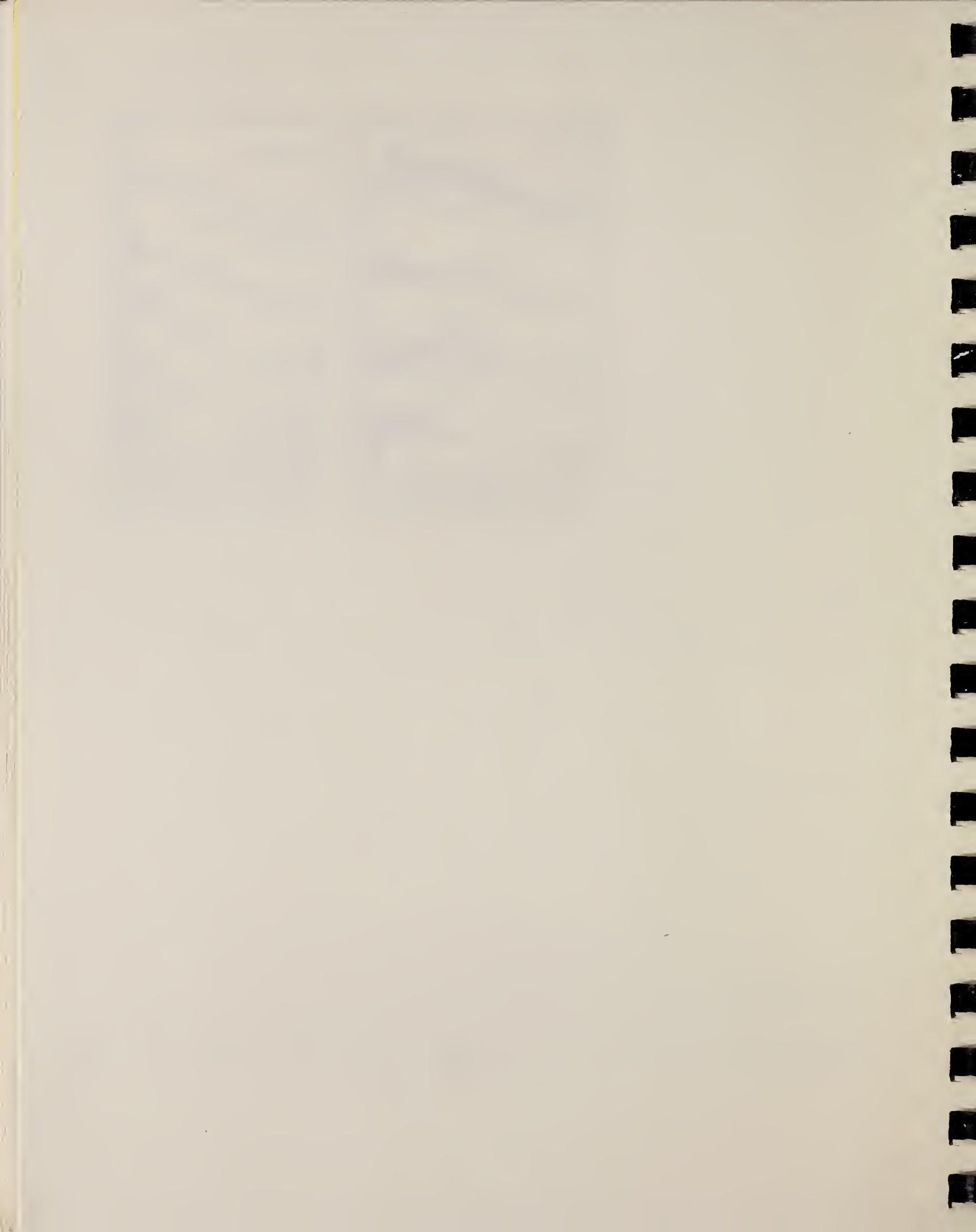


Fig. 2. Difference photopronot spectra (arb. units). The dotted curves indicate the difference photon spectra ( $E_T^m$  is the energy at the maxima).





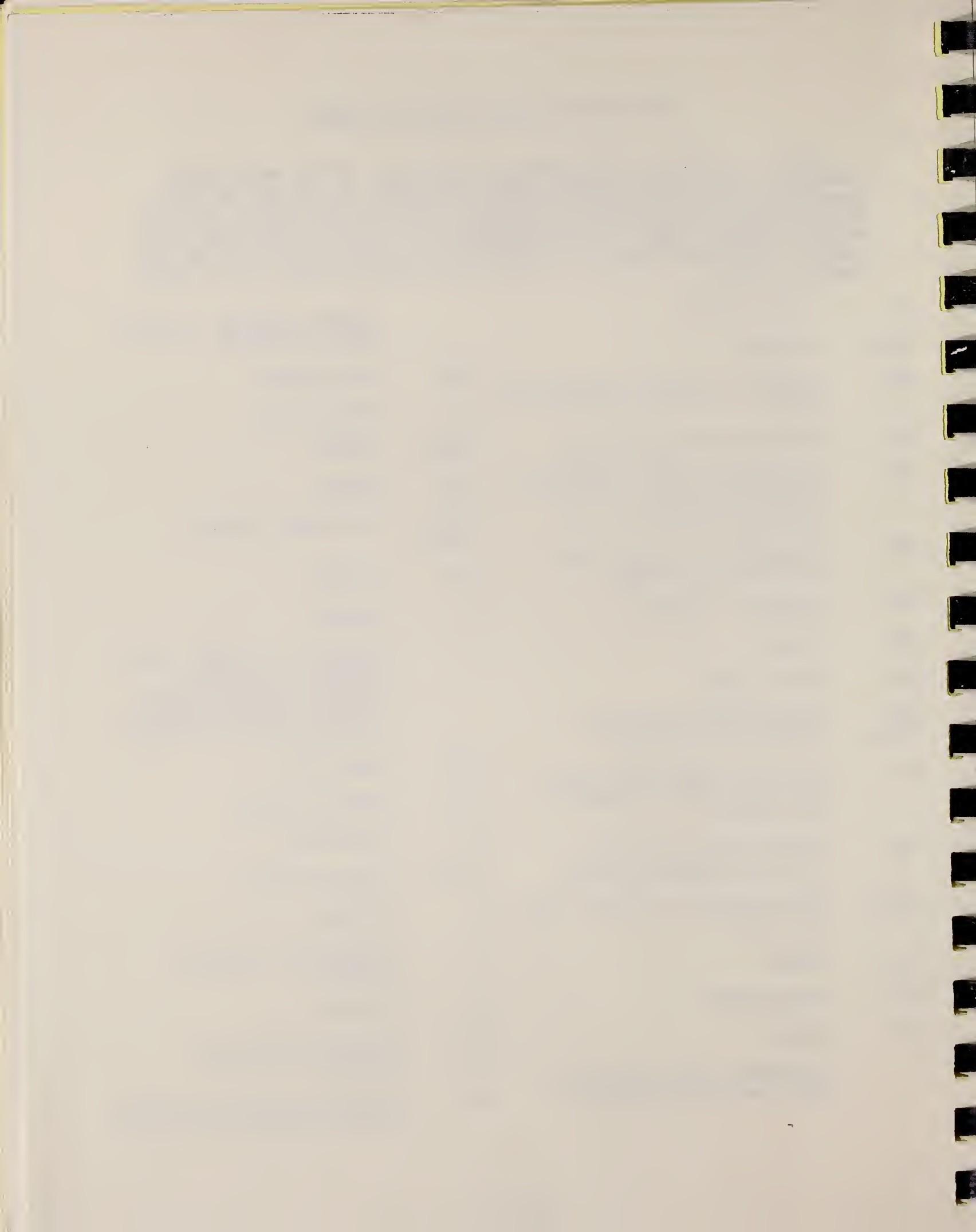




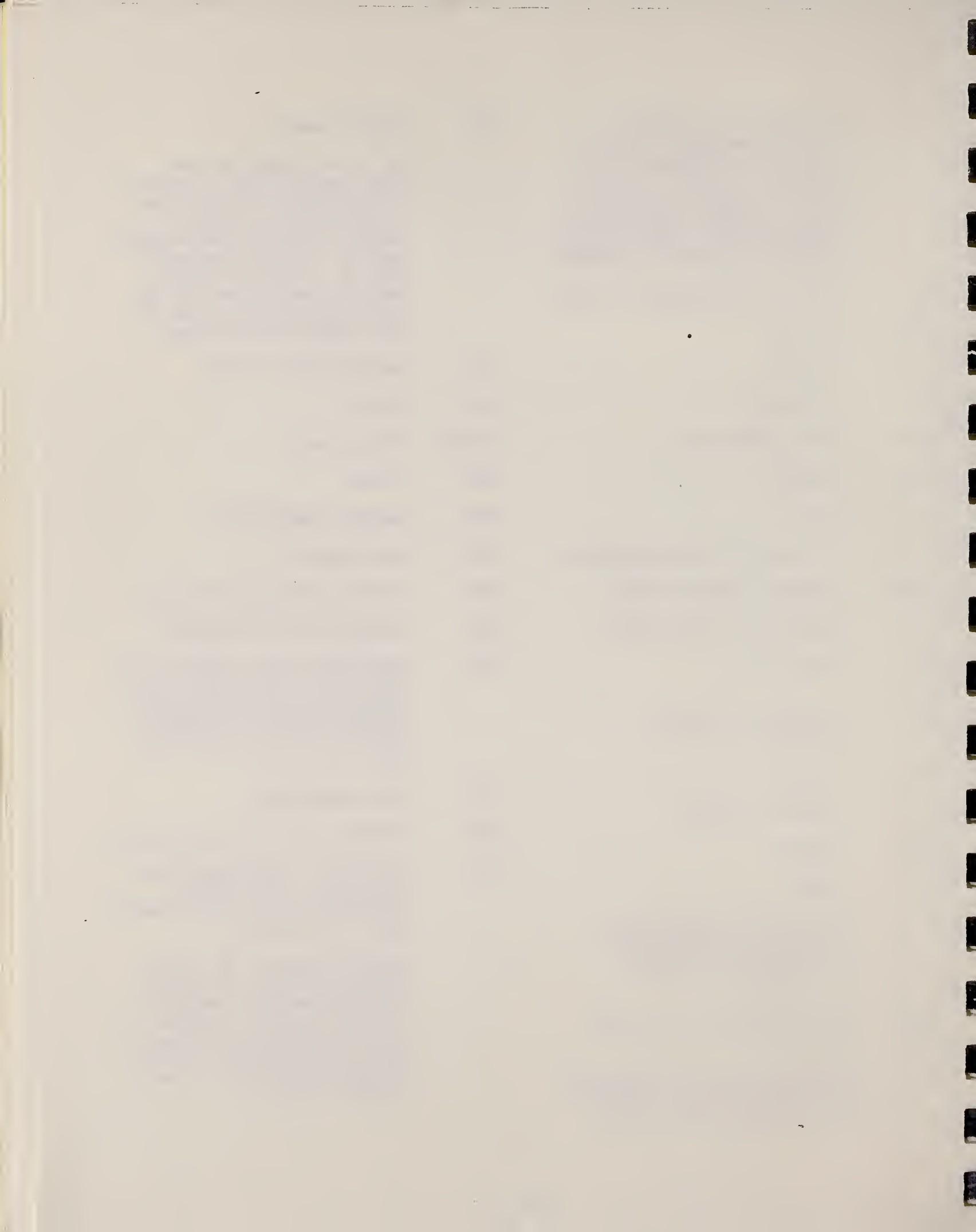
## DEFINITIONS OF ABBREVIATIONS AND SYMBOLS

Note: In this list definitions are given for various photoneutron reactions in which the following symbols are used: N, NL, nN, SN and XN. Corresponding definitions apply for reactions involving other nuclear particles where the symbols N (neutron) is replaced by, e.g. P, D, T, HE, A etc. Where unknown reactions result in the production of a specific radionuclide, the chemical symbol and mass number is listed as the reaction product, e.g. a G,NA22 reaction in  $^{59}\text{Co}$ .

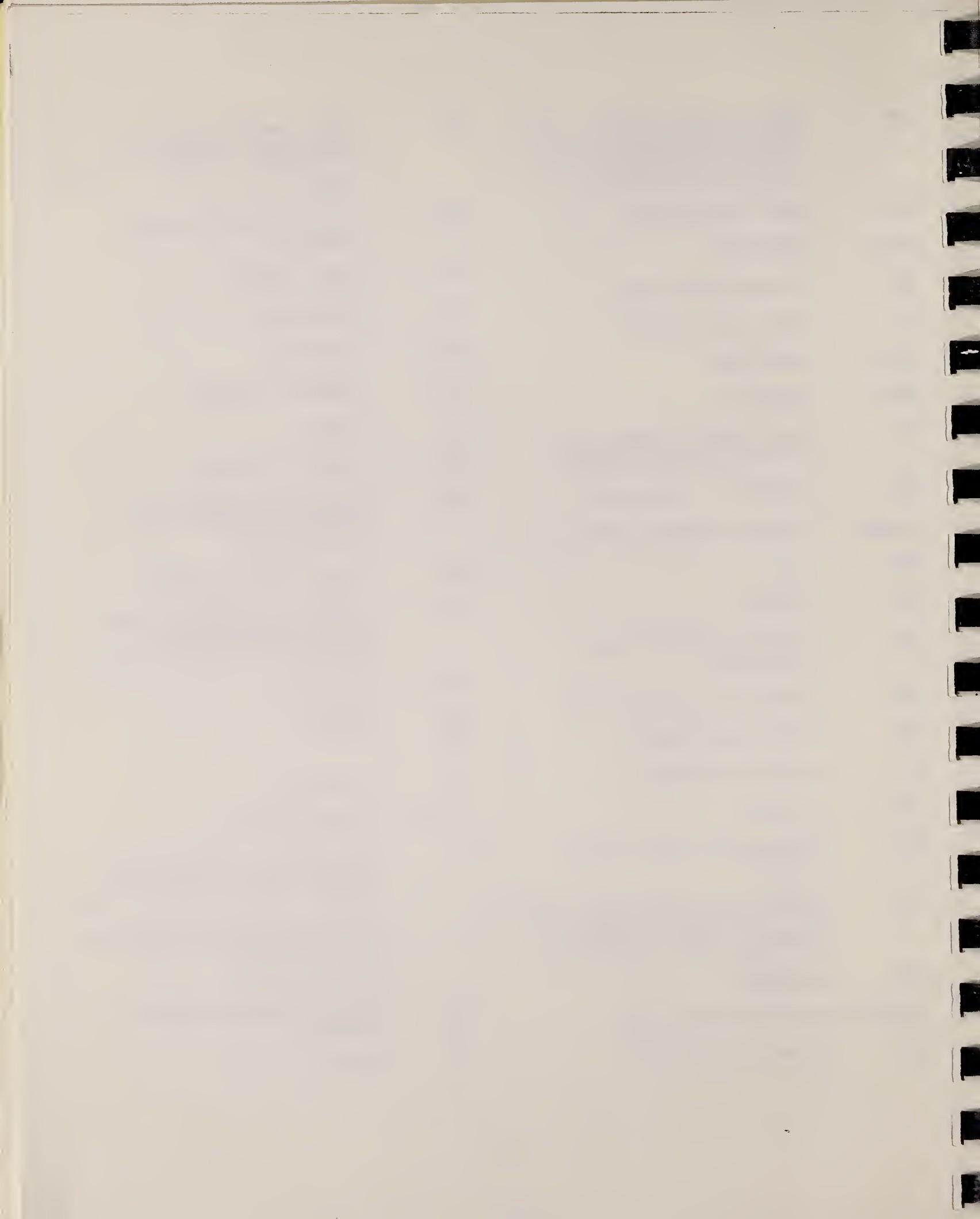
A	alpha particle		response function. Contrast with D = discrete.
ANAL	analysis	CCH	cloud chamber
ABI	absolute integrated cross-section data	CF	compared with
ABX	absolute cross-section data	CHRGD	charged
ABY	absolute yield data. Often means cross-section per equivalent quantum is listed.	CMPT	Compton
		COIN COINC	coincidence, coincide
ACT	measurement of induced radioactivity of the target	COH	coherent
ASM	asymmetric, asymmetry	CK	Cerenkov
AVG	average	D	deuteron or discrete. When discrete, it is used to describe a photon source or a detector response function. Contrast with C = continuous.
BBL	bubble chamber		
BEL B(EL)	reduced electric radiative transition probability	DLTE	energy loss
BF3	BF <sub>3</sub> neutron counter with moderator e.g., Halpern detector, long counter	DLTQ	momentum transfer
		DST	distribution
BML	reduced magnetic radiative transition probability, B(ML)	DT BAL	detailed balance
BREAKS	levels located by "breaks" in the yield curve	E	electron
BRKUP	breakup	E/	inelastically scattered electron
BRMS	bremsstrahlung	E+	positron
BTW	between	EDST	energy distribution or spectrum
C	continuous. Used to describe a photon source or a detector	E/N	used only to indicate a coincidence experiment as in (E,E/N).



N	N stands for any outgoing particle measured in coincidence with an inelastically scattered electron. Distinguish from e.g., (E,N) which is used to represent an electron induced reaction when only the outgoing particle N is detected.	KE	kinetic energy
EMU	emulsions (photographic plates)	L	may be an integer or zero that always follows a reaction product symbol. This is used to indicate transitions to specific states in the residual nuclide. When the letter is used as in (G,NL) the cross section given is that for the sum of transitions to two or more specific final states.
EXCIT	excited	LFT	excited state lifetime
F	fission	LIM	limit
FMF	form factor	LV,LVS	level, levels
FM-1	inverse femtometers	LQD	liquid
FRAG	fragment	MAG	magnetic spectrometer
G	photon	MEAS	measurement(s)
G/	inelastically scattered photon	MGC	magnetic Compton spectrometer
G-WIDTH	gamma-ray transition width	MGP	magnetic pair spectrometer
HAD	hadrons, hadron production	MOD	moderated neutron detector <u>not</u> employing a $\text{BF}_3$ counter, e.g. rhodium foil, Szilard-Chalmers reaction, $^3\text{He}$ , $^6\text{Li}$ reactions, GD loaded liquid scintillator, etc.
HE He3	$^3\text{He}$ particle	MSP	mass spectrometer
INT	interaction, integral, intensity	MULT	multiple, multipole, multiplicity
INC	includes	MU-T	used only in combination with G to indicate a total photon absorption cross section measurement, i.e. (G,MU-T)
ION	ionization chamber	N	neutron (see also XN and SN). The notation (G,N) is used to indicate a reaction in which only a single neutron is emitted, i.e. the reaction that can, in many cases, be measured by observing the radioactive decay of the residual nuclide.
ISOB	isobaric		
ISM	isomer		
J	multiplicity of particle defined by following symbol e.g. (G,PJN) with remark $J = 2,3,5,7$		
JPI J-PI	spin and parity of a nuclear state		
K	second multiplicity index, e.g. (G,JPKN) with both J & K positive integers greater than 1		



nN	where n is any integer. (G,nN) indicates the sum over all reaction cross sections in which n neutrons are emitted.	SN	sum of neutron producing reactions, $\sigma(\gamma, SN) = \sigma(\gamma, N) + \sigma(\gamma, NP) + \sigma(\gamma, 2N) + \sigma(\gamma, 3N) + \text{etc.}$
NAI	NaI(Tl) spectrometer	SPC	photon or particle energy spectrum
NEUT	neutron(s)	SPK	spark chamber
NOX	no cross-section data	SPL	spallation
P	proton (see also XP)	STAT	statistical
PART	particle(s)	SYM	symetric, symmetry
PHOT	photon(s)	T	triton
PI	pion, usually written as PI+, PI-, PIO to indicate charge	TEL	counter telescope
POL	polarized or polarization	THR	threshold for reaction or threshold detector, e.g., $^{29}\text{Si}(n, p)^{29}\text{Al}$ .
Q-SQUAR	momentum transfer squared ( $q^2$ )	TOF	time-of-flight detector
RCL	recoil	TRK	tracks of particles or fragments observed in solid materials (glass, mylar, etc.)
REL	relative	TRNS	transition
RLI	relative integrated cross-section data	UKN	unknown
RLX	relative cross-section data	UNK	
RSP	reaction spectrometer	VIB	vibrational
RLY	relative yield data	VIR PHOT	virtual photon(s)
SCTD	scattered	XN	all neutrons, total neutron yield, $\sigma(\gamma, XN) = \sigma(\gamma, N) + 2\sigma(\gamma, 2N) + 3\sigma(\gamma, 3N) + \sigma(\gamma, NP) + \text{etc.}$
SCD	semiconductor (solid state) detector	XP	all protons, total proton yield $\sigma(\gamma, XP) = \sigma(\gamma, P) + \sigma(\gamma, NP) + 2\sigma(\gamma, 2P) + \text{etc.}$
SCI	scintillator detector other than NaI, e.g., CsI, KI, organic (liquid or solid), stilbene, He	XX	reaction products defined in REMARKS
SEP	separation	XXX	
SEP ISOTP	separated isotope used	YLD	yield
SIG	SIGMA (cross section)		



4PI	a $4\pi$ geometry was used or a method like radioactivity or a total absorption measurement		products was determined. The polarized particle is indicated in REMARKS.
999	energy defined in REMARKS	* or @	
\$	indicates the measurement involved beams or targets that were either polarized or aligned, or that the polarization of the reaction		symbols used to indicate that the units associated with the numerals on one or both sides of the symbol in a specific column are not MeV. The units are defined in REMARKS.



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